Electro-etching handbook

a safe, non-toxic approach

Alfonso Crujera

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a safe, non-toxic approach

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Etching sometimes involves the use of sharp tools and dangerous materials or substances. Always follow the manufacturer's instructions and store chemicals (always clearly labelled) in a cool, dry and dark place safely out of children's reach.

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Workshops and Residency Programs

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Preface

An Electric Approach to the Art of Etching

Friedhard Kiekeben

Chicago, August 2013

Alfonso Crujera is not just a printmaking innovator, but also an accomplished painter, sculptor, and ceramic artist. His artwork and etching research is inspired by the breathtaking natural scenery of his native Canary Islands. The island of Grand Canaria was shaped by titanic forces millions of years ago. Such creation of worlds through volcanic eruptions and gradual erosion by the elements is mirrored by similar forces of erosion set in motion by artists using the medium of etching, on a small scale. According to Alfonso: "if you know how to watch, you can see earth moving, burning and crashing with the waves... Nature is so rugged and the same way so calm". Regarding his creative influences the artist once said that: "Tapies is my father in art, Picasso my grandfather and Van Gogh my great grandfather".

Since the year 2000 Alfonso Crujera became an influential pioneer in a technique of etching and printing that was previously little known, poorly understood by artists: electro-etching. This is surprising, as the method goes back nearly two centuries, and has been in use in various industries such as printing, electro-typing, and electro-plating (whilst being guarded by patents and copyrights). For a considerable amount of time electro-etching remained a mystery to most of us, despite its apparent simplicity. Far from being just an industrial process, electro etching can be a unique expressive medium that can fascinate any artist: pseudo-alchemical forces enable the marvelous transformation of metals through electrical attraction and the exchange of ions. Unlike chemical etching where metal surfaces just disappear and are carved into, here metals are magically removed only to be re-deposited elsewhere, changing from solid state into solution and back into solid metal as they migrate from anode to cathode.

And it is all made possible though the masterful use of electricity!

Ever since Rembrandt and Bosse artists had ample use of the creative vocabulary of erosion: etching is as much a unique artform as it is one of reproduction and printing. For centuries artists etching needs were largely satisfied through the easy availability of acids and chemical etching baths. Traditional acid etching using say nitric or hydrochloric acid solutions was easy to accomplish and highly effective. So why use electro-etching, a method that seemed complex and cumbersome? The answer is simple: traditional etching is typified by noxious and damaging fume emissions. Electro-etching, if practiced correctly promises to be the most health-conscious form of etching there is, whilst giving amazing creative results.

Some of the best minds of the scientific era tinkered with electricity. Volta and Galvani brought deceased frogs back into motion in the 1870s, Nikola Tesla made terrifying experiments with high voltages early in our century, and a few years ago Dolly the cloned sheep was brought into being through an electric spark. So it is of little surprise that even now many may think “man playing god” when electricity is at play. Indeed there is some justification to such fears, and the outstanding contribution Alfonso Crujera is making to the subject is all to do with making the method easy to understand, easy to control, hazard-free, and very accessible to artists.

Printmaking began moving away from acid toxicity in the late eighties when calls for safer printmaking became both a necessity and a reality. From the early experiments with new salt etch solutions by Nik Semenoff and Cedric Green it became clear that metal salts and electrolysis offer an ideal alternative to the brute force of the chemical reactions that are found in traditional acid etching. Electro-etching is an elegant and sophisticated exchange of metal ions with hardly any production of noxious fumes and harmful waste products and the creative results can be amazing. From the year 2000 onwards Alfonso Crujera extended his long-term exploration of etching into this new area, learning from peers such as Omri and Marion Behr, Cedric Green, and especially from his personal friend Ole Larsen. Humbly,

Alfonso Crujera acknowledges: “the new book is a summary of these three sources and my personal research”, yet it is quite clear that there is level of refinement, attention to detail, and simplicity in these methods that makes this research unique and very interesting not only to printmaking professionals but also to novices. “For electro-etching to work all you need is an e-e unit, a power-supply, a tank and sulphate, and the desire to work in a new way of etching. You can forget the fear to work with electricity”.

Long live electro-etching!

Foreword

Alfonso Crujera
Gran Canaria Island, August 2013

The idea of writing a handbook of electro-etching initially crossed my mind in August 2006. I was giving my first workshop to introduce the technique at the Centro de Arte El Jardinico in Caravaca, Murcia, Spain, as part of the annual call for international print workshops. I was surprised by the level of interest and curiosity this technique aroused among the etchers who attended the workshop. Encouraged by this group's eagerness to learn about electro-etching, I set out to write a detailed explanation of my experience –including its successes and failures– for those printmakers who, like me, are interested in learning about this method of etching in depth. In this book those who are unfamiliar with the technique may find a whole methodology to practice as an alternative to acid or toxic etching. I wrote and edited in 2008 the *Manual del Grabado electrolítico*, a handbook of electro-etching in Spanish. Since then, new developments have further shaped my experience of this technique and I will outline these in this new, English language edition of my handbook. In 2010 I wrote the article *Electro-etching made easy* for the website Nontoxic Printmaking & Printed Art (www.nontoxicprint.com). Following this, with the encouragement of Friedhard Kiekeben and Jennifer Helen Shaw, I decided to write this book in English with the generous help of Jennifer, who helped me in the first steps, with some of the finer points of the language. I then enlisted the help of Elizabeth Noone, who without any intaglio printmaking experience, was bold and daring enough to take on the job of finishing the translation of the whole handbook. But this book would not have its final English form without the invaluable help and advice of Bob Perkin, whose good humour, precision and intelligence in hunting out my errors have made the task easier.

Inevitably, there are some differences between this book and the Spanish version, but the foundations of the technique remain unchanged and, in keeping with the previous version, I have tried to improve and simplify the process for etchers in a such a way as to keep the costs of using this method realistic. As you will appreciate as you read this manual, electro-etching is in continuous development. Therefore, I have introduced new applications and a new chapter *Recent developments and work in progress* which discusses experimental applications, thanks to Master etchers who have generously shared their knowledge, and who have applied themselves to following this beautiful path of electro-etching.

In the Spanish handbook published in 2008 I thought it would be interesting to include the processes that use saline sulphate solution to etch aluminium, zinc and iron, as it was a practice that was still not very widespread. This gave artists who were not interested in electro-etching or could not work with electricity an alternative for etching in healthier conditions, avoiding acids. But the situation has changed and now there are more published works about saline sulphate etching; the process has become standardized and spread all over the world. For this reason I do not think it is necessary to cover it in this book because I could not add anything new.

Handbook

Introduction

With each step in processor growth, further experiments are necessary, so once again, it is time to explore.

Marion Behr

The last decade of the twentieth century and the early part of the twenty-first are surely one of the most interesting periods of research into contemporary intaglio printmaking techniques. Many printmakers became aware that materials used in workshops and art schools were harmful to health and the environment. Research which was focused in several areas showed that acid mordants could be replaced by sulphate and salt mordants or by etching with electricity, free of toxic fumes. It was found that methanol-based varnishes could be replaced by acrylic and oil-based resists; rosin and asphaltum powders by acrylic sprays; hydrocarbon solvents used for cleaning plates and inks by vegetable cleaning agents and cheap oil-seed products. Old procedures were rediscovered and new methods were incorporated using modern materials such as polymers for the practice of intaglio, digital and laser processes. Virtually all of these techniques have proved popular with those printmakers who are more health-conscious and environmentally aware, and among those who are curious and eager to experiment. Fortunately, these alternative processes have been gradually spreading across the world of modern print arts. Today, more and more publications and websites feature extensive information about these alternative methods.

Among the rediscovered techniques is electro-etching, developed in the 19th century by Thomas Spencer and then almost forgotten in the printmaking world. No one knows why. But now it has been revived through its association with safe or low-risk modern printmaking, thanks to research by Nik Semenoff, Cedric Green, Marion and Omri Behr, and the workshop of Öle Larsen. These printmakers have been testing and demonstrating the usefulness and safety of electrolytic

processes for etching. I have found through exhaustive testing that the electro-etching technique is one of the most appealing and efficient ways to non-toxically etch copper, zinc and iron plates. It offers a clean, deep bite that is hard to obtain using traditional techniques. How strange, then, that it is a process that is not well known, lacking an international profile and practiced by relatively few etchers. In addition to its sharp bite, there are several advantages that electro-etching has to offer:

- It does not generate toxic gases, as etching with acids does, and compared to acid solutions will not give off fumes when etching is not taking place.
- Because the electrolytic bite does not generate metal waste, there is no need to filter the electrolyte to remove waste nor is there the danger of the etched grooves (furrows) filling with waste and stopping the etching process.
- Electrolytic solutions do not become exhausted with repeated use, so it is easier to calculate the time of bite and solutions can be used for years.
- The process does not require the use of harmful rosin or asphaltum for aquatints; it is therefore resilient and sustainable. Indeed, *new galvanising effects* (an even less known technique) provide new graphic results with which to experiment.

In 2001, at the Atelje Larsen in Helsingborg, Sweden, assisted by Öle Larsen and Peter Sjöblom, I was introduced to the techniques of electro-etching on copper plates. Until then, neither I nor any members of the circle of etchers I belonged to had heard of this method of etching. At Atelje Larsen, little theoretical information on electrolysis was available except the text *Electroetch II. Safe solutions from start to finish: etching to steel facing, Marion Behr reports on developments* that had been published in the magazine Printmaking Today, (Vol 4, No 4, London, April 1995). In this article, the graphic artist Marion Behr reports briefly about her experiences with electro-etching, which had begun in 1989, (USA) in collaboration with Omri Behr, a PhD in Organic Chemistry.

Atelje Larsen, May 2001, Öle Larsen (back turned) and Alfonso Crujera.

I returned to my studio in Gran Canaria, fascinated by the results of the new technique. I decided to buy a small direct current (DC) power supply and using a plastic water container as an improvised vertical tank, started practising electro-etching. At the same time, looking for more information, I found the website of Marion and Omri Behr (www.electroetch.com) on which they outlined the history of electrolysis and revealed their experiments. I also came across Cedric Green's website (www.greenart.info) and later he sent me his handbook *Green Prints*. In both, he supplies a generous description of the technique of electrolytic etching, as well as information about saline sulfate mordants and non-toxic solvents. From this technical information I advanced a little further. I started to etch copper and zinc plates and I discovered something I considered very important: how to etch safely and how to work without affecting the water drainage systems and aquifers.

Thanks in large measure to the research and experience of these individuals, their proven successes, and the generous dissemination of their findings, electro-etching processes have been given a new lease of life and a rightful place in twenty-first century printmaking. We have a starting point and an open road to travel with our practice. I, and modern electro-etching, will always be indebted to their important contributions.

This handbook brings together these three sources of original and complementary research with my own personal research, showing the processes in a single volume. My hope is that the two editions of the handbook (first in Spanish, and now updated in English) will serve those interested in the technique and help disseminate the practice of non-toxic etching all over the world.

The reinvigorated technique offers a wide range of new features, graphic and innovative possibilities but has not enjoyed the same spread or level of acceptance as other non-toxic processes. This is perhaps because of an unfounded fear of using electricity, or the apparent "expensive paraphernalia" to set up an electro-etching unit. In truth, the electrical "know-how" is very simple, and you do not need expensive equipment.

I believe that electro-etching is a 21st century technique that is here to stay! And I hope to contribute to its revival and popularity by showing how with these easy instructions.

Note: I should clarify that this handbook is intended for the more experienced etcher, and requires some understanding of the traditional techniques of etching on metal plates.

Copper sulphate

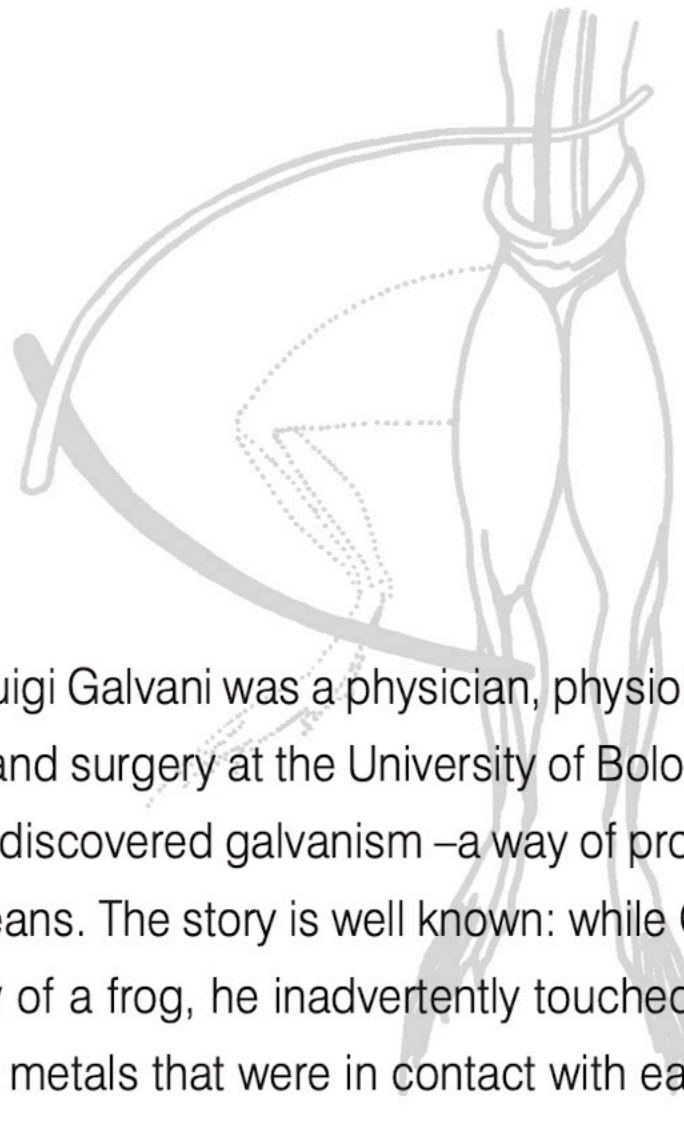


Illustration of
L. Galvani's discovery

The discovery of galvanism and electrolysis

The Italian Luigi Galvani was a physician, physiologist, and professor of anatomy and surgery at the University of Bologna. In the 1780s he accidentally discovered galvanism –a way of producing electricity by chemical means. The story is well known: while Galvani was dissecting the body of a frog, he inadvertently touched one of its legs with two different metals that were in contact with each other making the muscles twitch suddenly. This effect was attributed to a contraction of the muscle caused by touching the appropriate nerve. Further investigations by Galvani's contemporary Alessandro Volta, a physicist at the University of Pavia, showed that the nerves of the frog were not the cause of the electrical phenomenon. Two different metals, in contact with the fluid in the muscle, were enough to generate an electric current to cause twitches.

From these experiments, in 1800 Volta built the first lead acid galvanic battery. The "Voltaic pile", a direct current (DC) electricity source, was generated by a piece of apparatus consisting of alternating discs of zinc and copper separated by a sheet of paper or fabric, soaked in saline solution. This battery –a primitive energy source– led to further studies of galvanic electricity and the subsequent development of electrolysis.

In 1834 Michael Faraday, the English chemist and physicist, formulated the Laws of Electrolysis, taking as their starting point the phenomenon of the decomposition of chemical substances under the action of a current. For our interests, this can be summarized as follows: *The mass of a substance released at each electrode (anode and cathode) during electrolysis is directly proportional to the quantity of electricity passing through the electrolytic cell.*

More experiments and discoveries came in quick succession. Smee and Daniell improved the Voltaic pile using a zinc plate submerged in sulphuric acid and a copper plate submerged in copper sulphate. The German physicist and engineer Moritz Hermann von Jacobi invented "galvanoplastik", reproducing medals made of wax or plaster in an electrolytic solution connected to a galvanic battery. He published *Galvanoplastik* in 1840.

Around the same time, the Englishman Thomas Spencer, while experimenting with electrolytic processes, placed a copper plate coated with some resist varnish into an electrolyte and then connected it to the positive pole (terminal) of a battery. Again by accident, just like Galvani, he found that metal was deposited on the plate connected to the negative pole, while the plate connected to the positive pole was eroded. This suggested the idea of how to etch a plate using electrolysis. In 1840, Thomas Spencer and John Wilson obtained a patent for *Engraving Metals by Voltaic Electricity*. Electrolytic etching or as we will call it, electro-etching, had been born. Spencer continued his investigation into *galvanism* and *electro-etching* printing plates. The practical utility of the technique was also recognised as a quick method with which to reproduce medals and other objects. This process became known as *Electrotyping.*

In 1842, Franz W. von Kobell, a German mineralogist invented a technique for copying drawings by electrolysis and published *Galvanografi* outlining his method. In 1855, Charles V. Walker described these processes and their application to the art of engraving –which he termed *Electro-Etching*– in detail in his own book *Electrotype Manipulation*. In 1892, Hubert von Herkomer developed a technique similar to Kobell's, that he called *Spongotype*. The technique makes use of a mould through which an electrolytic process creates a plate that can later be printed according to the method known as *Galvanography*.

Graphics-related electrolysis experiments continued throughout the second half of the nineteenth century and into the first decade of the twentieth century both in Europe and the U.S. For some unknown

reason, however, the practice never really took hold in the fine arts. In complete contrast, in industry the processes were immediately taken up, developed and exploited for commercial purposes; they continue to be used right up to the present day. To cite one example, we have all heard of galvanised metal, where a metal is given a thin protective coating to prevent corrosion –this coating is applied by electrolysis.

There is little record of electrolytic processes being used in the fine arts until the mid-twentieth century. In the 60s, Stanley W. Hayter, from the famous Atelier 17 in Paris, France, mentions a process in which metal is deposited "electrolytically" in lines drawn on the varnish spread over a metal plate (a process also invented by Thomas Spencer). However, it is not until the late twentieth century, in the late '80s and early '90s, that artists and etchers began to publish more comprehensive work on this method.

Electrolysis in modern etching

In the American art magazine Leonardo (Issue No. 4, 1991), Canadians Nik Semenoff and Christine Christos published *Using dry toners in intaglio and electro-etching of metal plates* the results of their research into electro-etching. They drew attention to the unhealthy conditions in the etching workshops of Fine Arts Schools and Universities, and showed several non-toxic alternatives, including electro-etching. With the latter they used a different metal cathode to the plate that was etched and comparatively high voltages, between 2 and 6 volts.

In 1989, in the USA Marion Behr a printmaker-artist, and Omri Behr, a PhD in Organic Chemistry, concerned about the damage to health and the environment caused by the acid etching process, combined their knowledge and experience. They began experiments with electro-etching, based on the Schwuchow and Johnston American patent of 1912 for making halftone plates using electrolytic processes. Marion and Omri Behr investigated and developed an effective method for etching produced by electrolysis and, in 1992, patented their own electrolytic unit, known as the *Electroetch System*.

That same year, the Behrs published the article *Environmentally Safe Etching* in the Journal of Print World. Thereafter, throughout the

1990s, they published articles, taught workshops and made their experience and findings available on their website.

Around this same period, in Helsingborg, Sweden, electrolytic processes were also being developed in the Öle Larsen Atelje. In 1987, Peter Sjöblom began to experiment with electrolytic etching. This was as a result of reading a short paragraph in an old book on graphic arts that described an electrolytic technique for making multiple copies of a monotype on copper plates. Basing his research on practices and discoveries from the nineteenth century, besides etching by electrolysis, he developed a technique very similar to those of Kobell, Walker and Herkomer which he called *Polytypi*. In practice, this process is virtually the same as that which has thus far been called *Galvanography.*

In the mid-1990s, Cedric Green used his website to report his initiation in 1989, and subsequent experiences, with modern electrolytic etching processes. He created the term *Galv-Etch*, using the root "galv" to differentiate his methods from the ones that used the root "electro", but it is essentially the same technique that is called *ElectroEtch* by the Behrs. Green also developed other electrolytic applications which he interestingly calls, *Galv-on*, *Galv-plating*, *Bordeaux Etch.* In 2004 he published *Green Prints*, placing electrolytic techniques in the forefront of modern, non-toxic etching techniques, and vastly expanding the possibilities of the art form. Extracts from *Green Prints* have been translated and published in Spanish in the book *El grabado no tóxico: nuevos procedimientos y materiales*, edited by Eva Figueras, Barcelona University in 2004.

Principles of electrolysis and electro-etching

Two plates of the same metal, held parallel and separated, are placed into a salt solution of the same metal which is electrically conductive. The plates are connected to the two terminals of a direct current power supply or battery and an electric current flows from one plate to the other through the solution –the electrolyte. The electrolyte contains positive metal ions and negative sulphate ions. When the current flows,

positive and negative ions of the electrolyte are attracted to the plate of opposite polarity.

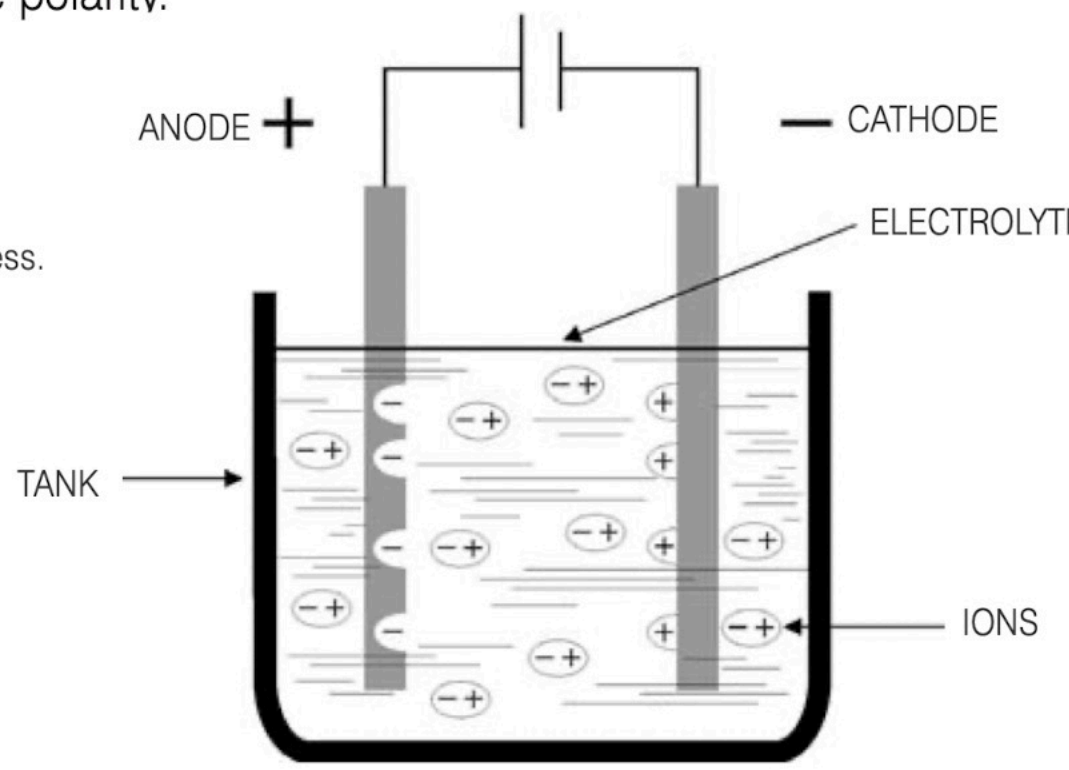


Illustration of electrolytic process.

Positive metal ions adhere or become “attached” to the cathode (negative pole) and the negative sulphate ions are attracted to the bare areas of the anode (positive pole) and react with the metal surface, oxidizing and eroding it. The result of this process is a bite in the metal that is comparable with that obtained by acid etching but with some very useful differences that we will see in this edition of the handbook.

In practical terms, the plate to be etched is immersed in the tank attached to the anode (+), facing and parallel to another plate that is attached to the cathode (-), with a distance of 6 to 10 centimetres between them. While positive metal ions are deposited as solid metal at the cathode, an equivalent amount of metal is being extracted from the anode, thus the electrolyte keeps its original concentration. The amount of sulphate in the solution does not change, and the electrolytic bath is reusable: the solution is not depleted with use. This balance and stability in the solution allows the calculation of bite-times more accurately than when using traditional acid etching.

By using the same etching parameters –time, voltage and concentration of electrolytic solution– for plates of the same size with similar etch areas the printmaker is able to produce a consistent bite with similar results on all the plates. This process does not release toxic gases such as those produced by etching zinc or copper plates with

nitric or hydrochloric acid. In addition, by taking some minor precautions when the plates are placed into and removed from tanks or during the washing process, it remains a fairly harmless technique.

Electrolytic processes, using electricity, have the advantage of not creating by-products such as gas bubbles, which with traditional acid etching can block the bite, nor sediment that can build up on the plate and at the bottom of a tank as with other methods.

The electro-etching workshop

My modest knowledge of electricity has not been a hindrance to using electro-etching techniques. The electro-etcher does not really need any special knowledge of electricity but only about the same amount of know-how as required to change a plug or a light switch. Understanding that direct current (DC) has two poles, one positive and the other negative, like a car battery or batteries for electronic devices, is pretty much all you need. If you are not sure about these basics of electricity or are a little nervous about the practicalities then you should consult an electrician to help you set up an electro-etching unit. Nevertheless, my intention is to describe the process graphically and clearly, so that any etcher will be able to set up the unit properly and safely, and will be able to experiment with the help of this handbook.

Power supply and electrolytic tank made with a plastic container. Very useful for small plates.

By taking some simple but essential precautions, electro-etching is considerably less risky than etching with acids. Once you have become comfortable and familiar with operating an electrolytic-etching unit, its advantages will be apparent.

The electro-etching workshop needs the same tools and equipment as a traditional intaglio shop: hot plates, rollers, marble slabs

for inking, an etching press, an area for damping paper, printing and drying, etc. The workshop does not require special modifications, just a table on which to put the electrolytic tank, ideally near a sink or basin, with drains and running water. The power supply can be located on a shelf next to the tank and at a safe distance from water. No specialist or expensive equipment is required. In fact, even though any workshop should be well ventilated, because this type of etching does not produce harmful gases, no special extraction devices, such as costly fume hoods, are needed. So, electro-etching is safety-conscious, cost-effective and achieves the quality of traditional etching.

The electro-etching unit

The electro-etching unit consists of, a power supply, a tank with two bar electrodes, the cathode plate (or grid), and the electrolyte. The plate to be etched is connected into this system.

Power supply

An important part of the electro-etching unit is the power supply which provides the direct current needed for the process. Some etchers successfully began their experiments using the current supplied by a car battery. This approach, however, is not easy to control, since the battery is slowly discharged during the process. Others have used a battery charger. A number of people who have been initiated in my courses have achieved electro-etching using the modest power supply of an electric toy-train or computer. For those who wish to obtain uniform and controlled results, my recommendation is to buy a power supply (DC) with digital displays, voltage and current (amperage) controls. These can be found from an online electronics retailer. These devices are very practical and provide a voltage of between 0 to 10 volts and a current of 16 amps. They can be obtained for about €350. Power supplies with a similar voltage range but with a reduced current output of around 3-4 amps can be purchased for less than €100.

As the voltage used in electro-etching is low, you only need a power supply that provides a controllable voltage range of between 0 to 9 volts and is capable of providing at least 10 amps of electrical

current. It is advisable that available amperage is as high as possible because, for reasons I will explain later, such an amperage will allow large plates or several smaller plates together to be etched according to the size of the available tank.

Vertical Tank

A plastic vertical tank is required –PVC (polyvinyl chloride) or PP (Polypropylene) about 45 cm deep, 45 cm long and 16 cm wide. This size of tank is suitable for accommodating medium-sized plates of about 35 to 40 cm along its longest side. Note, a metal tank should never be used. Tanks of this sort are not readily available commercially as there is little demand for them. It is possible to commission a PVC or PP plastics company to make a tank but this can be expensive. The simplest option is to look for other alternatives, such as containers made for other uses, and to adapt these to your needs. For example, some rectangular plastic containers for food products (ice cream tubs are often suitable), or a narrow plastic wastepaper bin.

Initially it is advisable to use small plates and an improvised tank made from a plastic water container with its top cut off until you become familiar with the technique –see the picture on page 26.

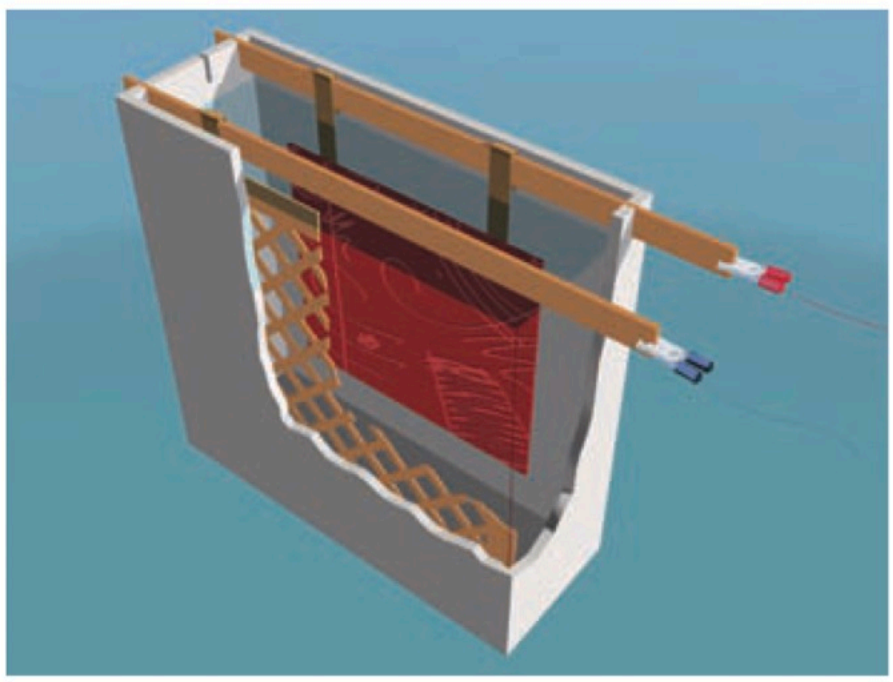
If the same tank is to be used to etch copper, zinc or iron, then a container with a plastic discharge tap at the base is useful. This enables easy draining of the tank so that it can be filled with the appropriate electrolytic solution for each metal. Alternatively, separate tanks can be used for each metal. Electrically, these may be connected

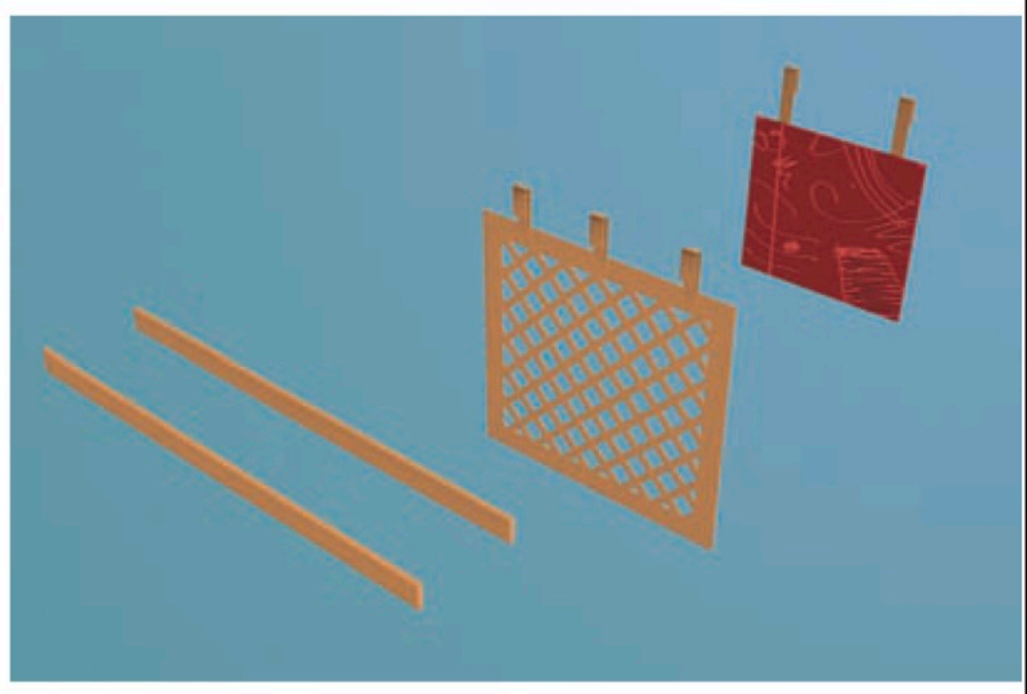
in parallel by their positive and negative electrodes, thereby using the same power supply to etch several plates at the same time –copper, zinc and iron– provided it has enough amperage. A large tank of the dimensions previously mentioned can hold two or more plates of the same metal side by side, the number depending on the size of the tank, to provide simultaneous etching.

On the left page, a power supply of 150 A and 9 V for large tanks and plates or several small plates, and a power supply of 3 A and 15 V for small plates or semi-dry electrolysis. On this page, power supply and container divided internally into two watertight tanks to etch copper and zinc. Below, 3D drawing of the electrolytic tank shows where the separate components are placed and the crocodile clips that connect the electrodes to the power supply. At the side, electrodes, cathode grid and plate to be etched.

It is also possible to use a deep, flat tray. A contact plate is placed at the bottom of the tray with the plate that is to be etched laid on top. The back of this etching plate* is unprotected. A cathode grid is hung above these plates at a distance of several centimetres. The contact plate and cathode grid are then connected to the power supply. On his website Cedric Green explains the flat tray method in detail. I prefer to use a vertical tank as I find it safer and more convenient.

*The side that is in contact with the contact plate.



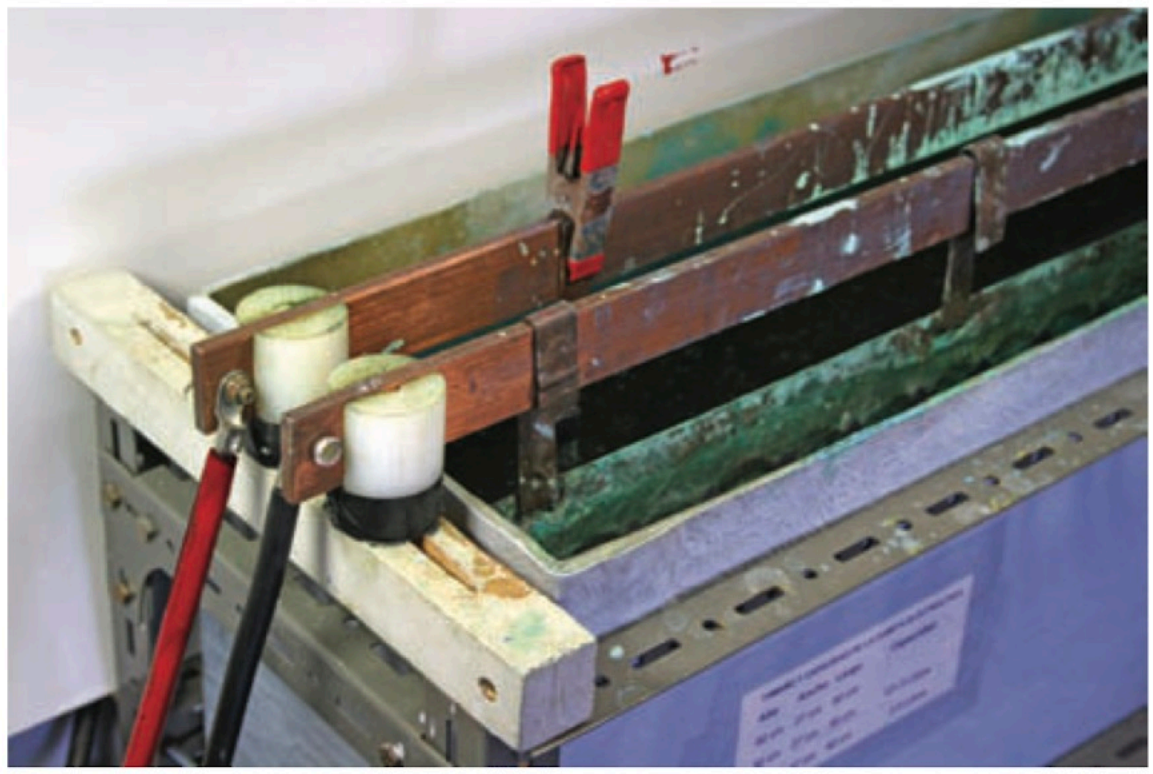


Electrodes and cathode plate

The electrode bars provide the electrical connection between the power supply and the cathode plate and the plate to be etched. They can be used as "cross-bars" from which to hang these plates; this makes the handling easy.

Two copper electrode bars can be laid across the top of the tank; they must not be in contact with the electrolyte. Copper is used because it is the best electrical conductor.

Each electrode bar can be about 0.3 cm thick, 2 cm wide, and about 4 cm longer than the length of the tank because they will need to extend about 2 cm on each side of it. The cathode, and etching plate(s) are hung from them. The bars are the positive and negative poles respectively and are connected to the positive (red) and negative (black) output connectors of the power supply. These electrode bars stick out a few centimetres on either side of the top of the tank. To secure them, cut slots in the rim of the tank into which they can be inserted. The first pair of slots should be positioned about 1 cm from the front of the tank –this is where one copper bar can be slotted in: this is the cathode (-). In parallel, at a distance of about 6 cm, cut another pair of slots into which the second copper bar can be slotted: this will be the anode (+). Other slots can be added up to 10 cm from the cathode to allow the etcher to experiment with different distances between both poles –see 3D drawing on page 29.



Detail of the tank showing the electrodes from which the plates hang. These electrodes have been mounted on two mobile supports in order to allow the distance between them to be altered.

The distance between the anode and cathode will be practically the same as between the plate we are etching (connected to the positive anode) and the cathode plate (connected to the negative pole). The distance between the plates used by different practitioners varies between 2 cm and 10 cm. However, I believe that 2 cm is too narrow

and runs the risk of the plates coming into contact, thereby causing a short circuit that may damage the power supply.

The distance between the plates that I normally use ranges between 6 and 10 cm. It should be borne in mind that the distance between the etching plate (the anode) and cathode plate or grid, determines the strength of the electrolytic action, which is proportional to this distance. It is up to each etcher to experiment with this parameter, although it is safer for the beginner to start with an electrode spacing of 10 cm which can later be reduced to 6 cm.

With a simple tank using a sufficiently narrow plastic container, the etching plate and the plate cathode can be hung from the top edges and connected directly to the power supply with two crocodile clips.

Cathode plate or cathode grid

Basically, the cathode plate must have the following features:

- It must be made from the same metal as the plate being etched. A thinner plate of the same type as those being etched can be used –1 mm is thick enough.
- It should be as wide as the front of the tank, so that a single large plate, or several smaller ones side by side, can be etched, taking full advantage of the size of the tank. The face of the etching plates should always be in front of and parallel to the cathode plate, never tilted.
- It can remain permanently in the tank. When the unit is not in use, there is no flow of electric current so it is not necessary to remove the cathode plate as it will not be affected even when submerged in the electrolyte.

While developing my electro-etching techniques, I have evolved and improved on the basic cathode design (the original can still be used however). In the beginning I used a completely solid, flat plate as a cathode, and of course, it was made of the same metal as the plate that I was etching. However, the electrolytic process has an inherent effect: a tendency to bite more intensely at the edges of the plate than in the centre of it. This is known as the *edge effect*.

The edge effect

The voltage across the two electrodes produces an "electric field" in the electrolyte. It is shown schematically by the dotted lines in the figure with the lines showing the direction of the electric field.This electric field drives the positive and negative ions in the electrolyte towards their respective plates which creates the electric current. It can be seen that there is a concentration of the electric field and consequently the current at the edge of the plates.

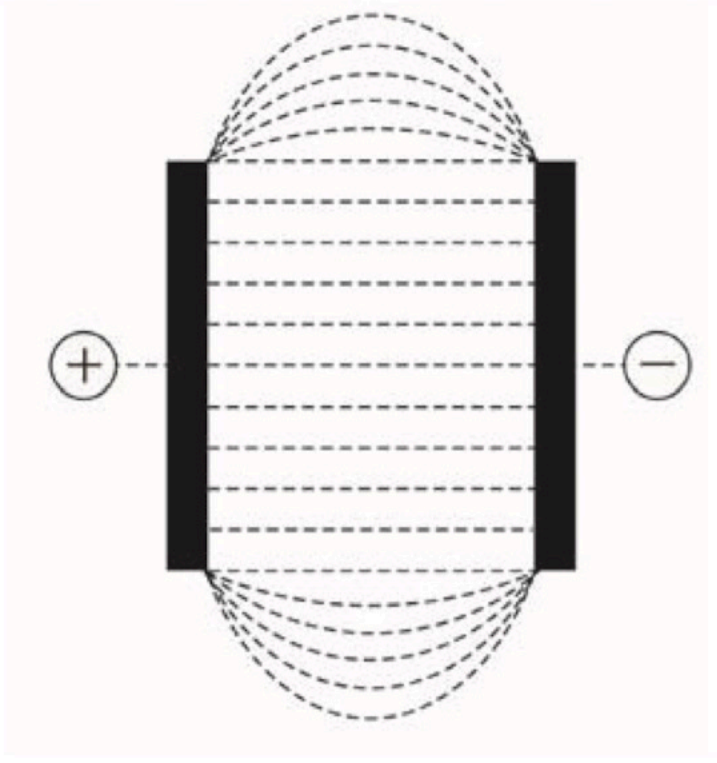


Illustration of edge effect.

It can be shown that at the edges the current is about 1.3 times larger than the current at the centre of the plate. This is a lot and may lead to uneven etching. To counteract this edge effect a cathode grid is used instead of a full plate.

Unable to make it myself, I decided to go to a metalwork shop to ask them to perforate a plate of zinc and another one of copper (as shown in the pictures). These perforated plates worked much better than a solid plate.

On the left, a zinc cathode grid and, on the right, a copper cathode grid.

The cathode plate hangs from the electrode by two strips of the same metal which are either riveted to the plate using the same metal, or soldered with tin or any metal that is different from the plate. The joint areas should be covered with several coats of metal varnish,

Detail of the joints of the strips of metal in the cathode grid.

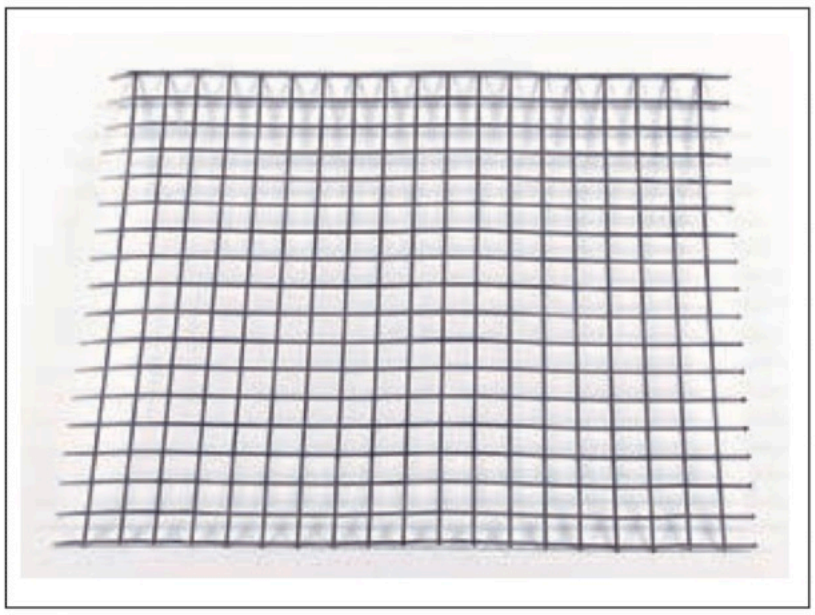
otherwise the electrolytic action will corrode these other metals. Crocodile clips should be used at the point of contact between the strips and the negative electrode bar to ensure good electrical contact between them.

Later I found that using a stainless steel grid as a cathode, instead of a copper or zinc die-cut plate, also worked extremely well. What was just as pleasing, it was cheaper! Stainless steel grids are industrially produced and readily available from all sorts of outlets. They are also galvanised and will not be corroded by the electrolyte. Always use one grid for each type of metal to be etched.

However, do not put a zinc-galvanised grid into an electrolyte of copper sulphate, since it will be corroded even without electricity and will weaken the solution.

I often use an electro-welded grid with squares of 11 mm and 1.5 mm thick wires. The space between the wires should be less than, or the same as, the distance between the electrodes.

I now hang the cathode grid from the electrodes differently. The grid width measures a few centimetres less that the front of the tank, and its height measures one or two centimetres less from the tank bottom to the top edge of the electrode. For the electrical contact,



On the left, stainless steel cathode grid, on the right, clips to make electrical contact with the cathode grid.

I use clips covered with self-adhesive plastic to protect them from corrosion by the sulphates.

When etching zinc plates the electrolyte is zinc sulphate diluted in water and the contact-strips used to hang the etching plate and

the cathode plate must also be made of zinc. These will be in contact with the copper electrodes bars outside of the solution. In the case of copper plates, a solution of copper sulphate is used and the contact-strips made of copper. Similarly for etching iron the strips are made from iron and a ferrous sulphate solution is used. Remember: It is important to keep the solutions clean. Once the tank is ready, the electrolyte can be prepared.

Electrolytes

The electrically conductive salt solution is the electrolyte. It must have a cation (a positively charged ion) that is the same as the metal to be etched. Early experiments in electrolytic etching used a solution of sodium chloride (common salt), and for this reason they were not very successful. Modern electro-etching experiences tell us that an electrolyte must generally use a salt dissolved in water containing positive ions that are the same as the metal to be etched. However, see section *Recent developments and work in progress* on page 113. So remember, you must use a metal salt that matches the metal to be etched:

- Copper sulphate ($Cu\ SO_4$) for copper plates
- Zinc sulphate ($Zn\ SO_4$) for zinc plates
- Ferrous sulphate ($Fe\ SO_4$) or ammonium ferrous sulphate ($NH_4\ Fe\ (SO_4)_2$) for iron and steel plates

Zinc sulphate on the left, copper sulphate in the middle and ferrous sulphate on the right.

These sulphates can be obtained from industrial chemical suppliers. These grades of sulphate may be more expensive than commercial products that contain them as a main but not sole ingredient, but they will contain less impurities and thus have better etching properties.

Since the electrolyte solutions are not exhausted with successive bites and therefore do not have to be continually changed, the amount of sulphates used is small. Consequently, I would advise using grades of maximum purity. Copper sulphate is more readily available, but if acquired in garden stores, take care that it has not been mixed with other products such as fungicides, etc., as the resulting electrolyte may not work.

The concentration of metal ions in the electrolytic solution will determine the electric current flow and consequently the amount of metal that will be removed from the plate you are etching. Low concentrations work more slowly but etch effectively. Saturated concentrations are faster but require a power supply with more amperage. A high concentration combined with a high voltage can result in the generation of oxygen at the anode, forming –if the plate is copper– a thin but solid oxide layer. This is not dangerous but can stop the etching action as the copper oxide is not electrically conductive. If this happens the electrolyte must be diluted.

If the plate is zinc, the electrolytic solution is fairly concentrated and a high voltage is used; the solution will slowly begin to change and zinc hydroxide is generated. As zinc hydroxide is very alkaline, it will increase the pH of the solution and thicken it. These factors influenced the earliest attempts at anodic etching and led to the use of acids to neutralize the effects.

There were etchers who added a small amount of sulphuric acid (0.03% / litre of solution) to their copper sulphate solution to prevent unwanted oxidations –something which works on copper plates. However, it is not recommended that sulphuric acid be added to zinc sulphate solutions since the current flow will produce a large quantity of gas.

By keeping the electrolyte concentration within the range that will be explained later, we will have no problems and can avoid using hazardous sulphuric acid to neutralize the pH of the solution. In fact, printmakers who are working on modern electro-etching as an alternative to acid etching are not willing to use it even in small quantities.

Sulphates of copper, zinc or iron (ferrous) are salts which are usually supplied in the form of crystals or sometimes crushed into coarse grains.

When handling these crystals or powders, you should avoid breathing in the dust or allowing the material to come into direct contact with the skin or eyes: use a dust mask, rubber gloves and safety glasses for protection. Once the salts are diluted in water there is no danger of breathing them so the face mask may no longer be required. The solutions are safe because, as explained above, they do not emit harmful gases. Skin contact with the electrolyte solutions is to be avoided and care should be taken to avoid splashing when immersing or removing plates from the tanks. However, if this does occur, the affected skin should be rinsed with water. For contact with eyes, immediately rinse with a saline solution or water and seek medical advice.

Preferably, electrolytic solutions should be made with pH neutral water (distilled or deionised) so that the chemistry of the electrolyte will be more balanced.

If copper sulphate is supplied in crystal form it dissolves more easily in hot water (using a temperature of approximately 35° to 45°C). By comparison, zinc and ferrous sulphate are more easily dissolved. If supplied in powder form do not forget the use of a dust mask and rubber gloves while preparing the solutions from the solid sulphates.

Prepare the electrolyte in a separate plastic container before filling the etching tank: it can be filtered if necessary. Remember, a wooden stick, never metal, should be used to stir the salts in the water. Initially, a small amount of the sulphate salts are added to the water which is stirred gently. The mixture is left to stand for a few minutes and then more sulphate is added. The crystals should be stirred until they are completely dissolved.

There are several concentrations that I have worked with, each one of them giving slightly different results. The concentration is measured as the amount of salt per litre of water. For initial experiments

I recommend starting with a low concentration solution. Later, if the amperage of the power supply is sufficient, the effects of other and larger concentrations can be explored.

Electrolyte for etching copper plates

Weak: 160 g copper sulphate to 1 litre of water. Marion and Omri Behr use this solution, which is less concentrated.
Medium: 200 g copper sulphate to 1 litre of water.
This solution is used in Atelje Larsen.
Strong: 250 g copper sulphate to 1 litre of water. This is a more concentrated solution recommended by Cedric Green.

Electrolyte for etching zinc plates

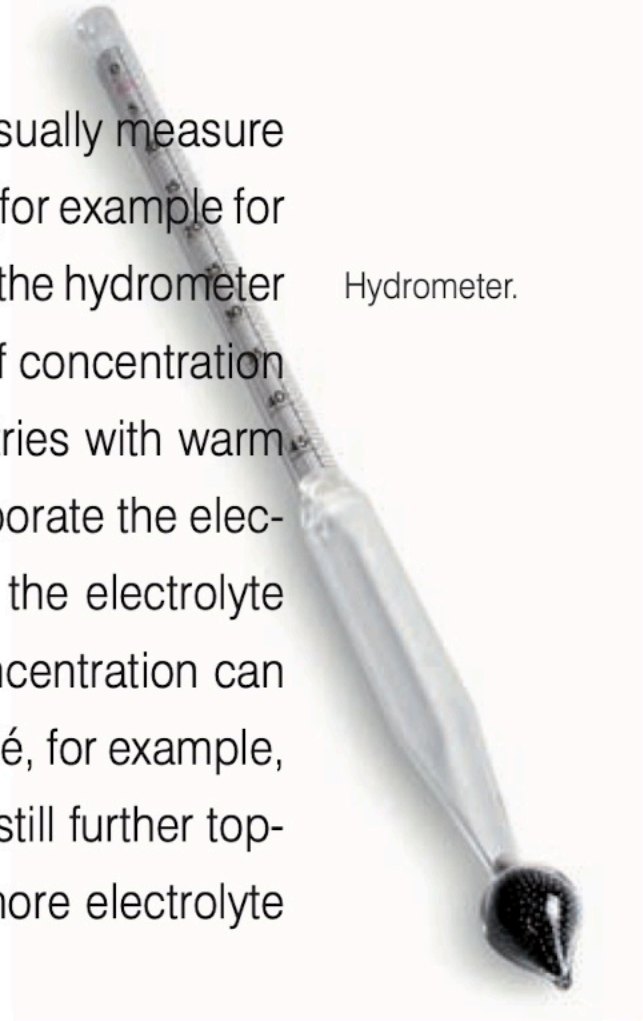
Weak: 160 g zinc sulphate to 1 litre of water. Marion and Omri Behr use this solution, which is less concentrated.
Medium: 250 g zinc sulphate to 1 litre of water. This is the one I use, but I also had good results with 300 g/litre of water.
Strong: 500 g zinc sulphate to 1 litre of water. This is a more concentrated solution recommended by Cedric Green.

Electrolyte for etching iron plates

Weak: 200 g ferrous sulphate to 1 litre of water.
Medium: 250 g ferrous sulphate to 1 litre of water.
Both used by me.

I have experimented with all these combinations and have obtained excellent results. Later, when I explain the different techniques of etching, I will mention the concentrations used for each technique.

When I have finished preparing the electrolyte, I usually measure the concentration of the electrolyte with a hydrometer (for example for a copper sulphate concentration of 250 g/litre of water the hydrometer indicates 23.5º Bé -"Bé" stands for Baumé the units of concentration for the hydrometer). This can be very useful in countries with warm climates, where it is very common for the heat to evaporate the electrolyte from large open tanks. With time the level of the electrolyte may decrease and any corresponding change in concentration can be measured with the hydrometer. If it measures 25º Bé, for example, top-up with water until it measures 23.5º Bé again. If still further topping up is required to obtain the correct level then more electrolyte must be prepared and added to the tank.



Hydrometer.

To avoid evaporation from large open tanks, cover the whole surface of the solution with ping-pong (table tennis) balls. These work as an insulating blanket and reduce evaporation. This is an old method used in some galvanising craft workshops. It works, I have tested it! If the resists are very dry you can immerse plates without having to remove the balls, however they will have to be taken out when working with soft-ground.

Ping-pong balls insulating blanket.

The temperature of the solution is very important. The electrolytic bath should be kept below 32ºC to prevent the electrolyte penetrating between the metal and the resist.

Electrolyte solutions that are not being used can be left in the vertical tank. Cover the tank to avoid contamination of the solution or evaporation in warm weather. If you are using small quantities, the solutions can be stored in plastic bottles with caps, with a label indicating the properties such as concentration of sulphates and date of preparation.

For those who want to begin etching using this handbook, my advice is to prepare a low concentration electrolyte and practice the different processes until you are familiar with them and have achieved

good results. Then you can try using more saturated concentrations and decide for yourself which solution is most appropriate for your style and way of working.

Current and voltage

Before turning on the power supply to start the etching, it must be borne in mind that in an electrolytic tank the electro-chemistry may be complex. However, it is not necessary to understand this chemistry as long as you understand the process and take care to follow the right steps to achieve the best results –see the footnote on page 127.

When the plate has been prepared and placed in the tank, to begin electro-etching it is only necessary to switch on the electrical power and set the volts and electrical current (amperage).

Note, do not make or alter electrical connections or handle plates while current is flowing in the electrolytic unit: switch off the power supply first.

The amperage is the amount of current (amperes or "amps") that flows between the two electrodes, in our case between the cathode plate and the "etching" plate. Amperage will be proportional to the amount of bare metal on the plate to be etched, where electrolysis is taking place. The display on the power supply can be used to monitor the amperage. A plate drawn with needle lines shows lower amperage than a plate with wide areas of bare metal.

The depth of the lines produced by electro-etching is proportional to the etching time and the amount of electrical current flowing through the electrolyte solution (depth $\propto$ current x time). Consequently by increasing the current the etching time can be decreased. It is important to understand that the amount of current which can flow depends on how much bare metal is available for etching. This bare metal is a result of the lines made in the ground when the image was drawn onto the plate with a needle or arises from open areas of metal which have been left so that micro dots can be generated –see section *Electrotint* on page 62.

Before starting to etching remember that you are going to be working with a low voltage.

If a voltage as high as 10 volts is used for etching, the conductive solution generates hydrogen at the cathode and oxygen at the anode. It is possible for the hydrogen and oxygen gases to combine and explode on contact with a single spark, such as that which may be caused by a switch. To avoid this simply etch with low voltages. Some practitioners recommend not going above 6 volts. My first experience with electro-etching was at a very low voltage –0.5 volts– and even with this I could etch lines of different sizes and depths, and diverse tonal effects. I have also experimented with 1 and 2 volts, but the results have not been so remarkable as to encourage further testing with higher voltages. My work has always been done using a range of between 0.5 and 1 volts, and I have not needed to increase voltage to achieve new or different effects.

The experiences of Marion and Omri Behr tell us that with 6 volts, layers of resist peel off within 2 minutes of electrolytic action, and the strongest resist is affected after 10 minutes. Needle lines are etched deeply at 12 minutes, while the metal between cross-hatched lines erodes at 10 minutes.

With a high voltage the electrolytic action on a wide bare area of the plate* does not provide a tonal area of micro dots with deeper greys, and may be paler than at low voltage –see *Electrotint* on page 62.

*Open bite.

Consequently, I strongly recommend that you use a very low voltage, for example 0.5 volts. However if you want to experiment with a slightly higher voltage, use no more than 2 volts.

Never run unnecessary risks by raising the voltage because it can generate hydrogen and oxygen, which may turn the gentle art of *non-toxic electro-etching* into a more hazardous pastime. Some authors call electro-etching *Low voltage anodic etching*, a name I would like

to use if it were not so long, because it tells us clearly what we are doing and how we do it.

To make things clear and easy to follow, throughout this handbook I will indicate the voltage used with each process. A summary of the recommended concentrations, voltage and etching times for the different metals is also provided in the *Data charts* on pages 176-178.

Etching with electrolysis

Metal for etching plates

A local importer supplies me with 1mm thick industrial sheets of copper and zinc. I choose these sheets carefully, making sure that there are no scratches caused by transportation. I make the cathodes and contact-strips of each metal from these same sheets.

Iron is another metal that can be electro-etched with excellent results. I was not accustomed to using this material for etching by the conventional technique because it uses nitric acid to bite the plates and the corrosion of this metal releases such an amount of toxic gas that it has never interested me.

One of the other disadvantages of this metal is the ease with which it oxidises, obliging the etcher to guard against it because the surface of the plate becomes damaged which ruins the work carried out. However, there are artists who use this oxidisation to advantage as a graphic effect. One benefit of iron plates is their price. They are much cheaper than copper or zinc and are easily obtained from any industrial metal supplier or recycler. There are countries where it is not easy to obtain copper or zinc, or they are so expensive that printers are obliged to work with iron.

At an electro-etching workshop I gave in Monterrey, Mexico, in 2009 during an international non toxic printmaking meeting *Notóxico, Encuentro Internacional de Grabado 09*, I realised how widespread the etching of iron with toxic nitric acid was among the etchers in that country. Because of this, we started etching iron plates using the process of electrolysis. At a workshop I gave months later in the Centro de las Artes de San Agustín in Etla, Oaxaca, Mexico, the printers were able to discover the advantages offered by applying

the electrolytic process to iron. Later I will relate a very interesting experience using this metal that took place in an etching workshop in Zacatecas, Mexico.

So, in this new edition of the handbook, I will relate my experiences etching iron plates with electrolysis as an alternative to the unhealthy process of etching with nitric acid. I hope that these experiences will be useful for printers who want to use this metal.

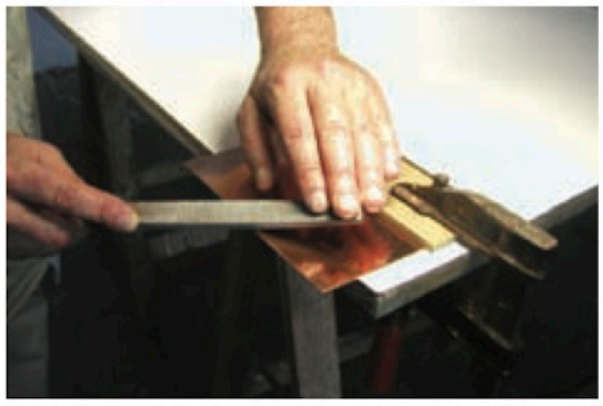
Another material that is often used for etching is aluminium with *copper sulphate mordant* (see the articles by Nik Semenoff and Friedhard Kiekeben on their websites. Addresses at the end of this book). Because of its price, which is considerably cheaper than copper or zinc, its use has spread rapidly in workshops and art schools. Through the emails I receive and the workshops I give I have realised that printmakers are interested in knowing how to etch aluminium using electrolysis. I must confess that my past experience with this material has not been satisfactory. However more recent results are encouraging –see the later section *Recent developments and work in progress* on page 113.

Preparing the plate

The plate is prepared for etching in the following order, as may be seen from the pictures:

- Cut the plate to size and remove any rough edges
- Clean the faces of the plate with wet and dry sanding paper
- Stick the contact strip to the back of the plate, covering the back completely with the self adhesive plastic
- Degrease the front of the plate
- Apply the ground to the front of the plate
- Use the appropriate tools to make the image on the ground
- Electro-etch the plate.

Once the plates have been cut to the correct size, remove the ridges left by the shears by bevelling the edges with a file. Then polish the front of the plate (the surface to be etched) with fine “wet and dry” sanding paper. Once polished and dry, the contact-strip has to be positioned and attached.



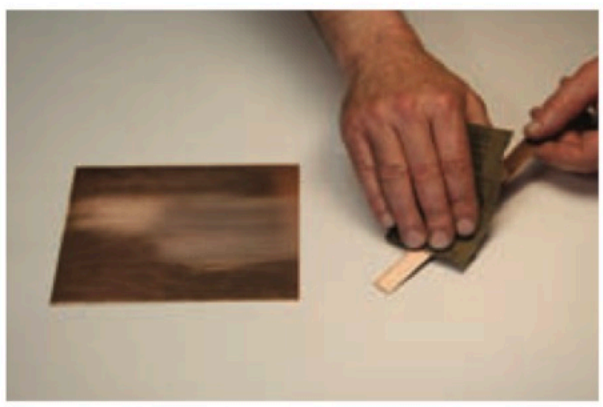
Steps in preparing the plate.

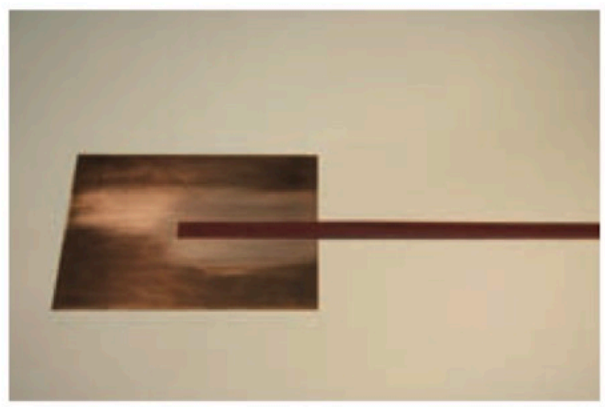
Remember to use a contact-strip of the same metal as the plate which is to be etched.

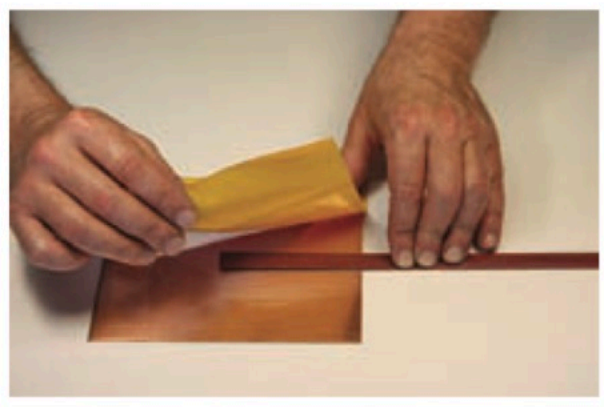
The contact-strip

The purpose of the contact-strip is to conduct electricity to the plate. I cut strips of 1mm thick, 1.5 cm wide and 30 cm long. I adapt the length of the contact-strip so that it reaches from the electrode to several centimetres beneath the surface of the electrolyte as the etching plate must be completely submerged –see diagram of the tank on page 29. I stock up on a good number of these strips which will be re-used. To obtain a good distribution of the electric current, the strip is placed in the centre of the back of the plate. I usually sand the area of contact of both the plate and the contact-strip to ensure a good electrical contact and flow of electricity. If the strip has previously been used for etching then it is advisable to clean the area of contact well with a file or sandpaper. It is very important that the areas of electrical contact between the different components are always cleaned properly.

Steps in preparing the contact-strip.





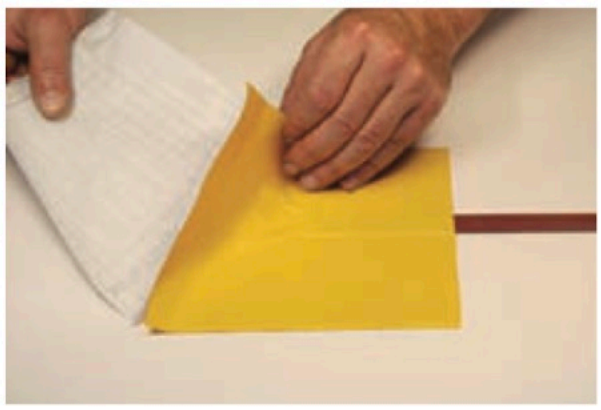
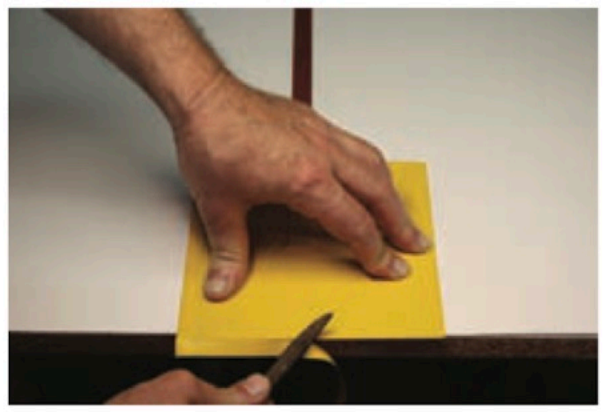
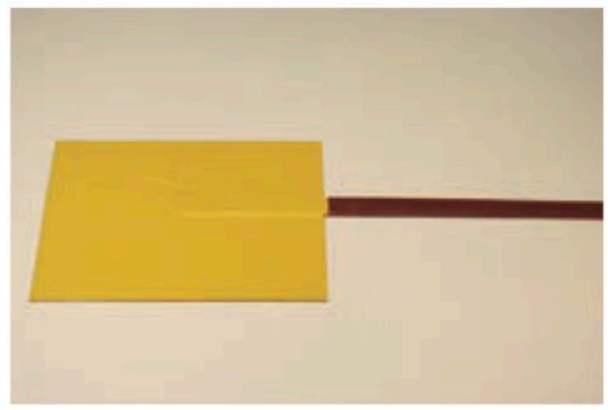


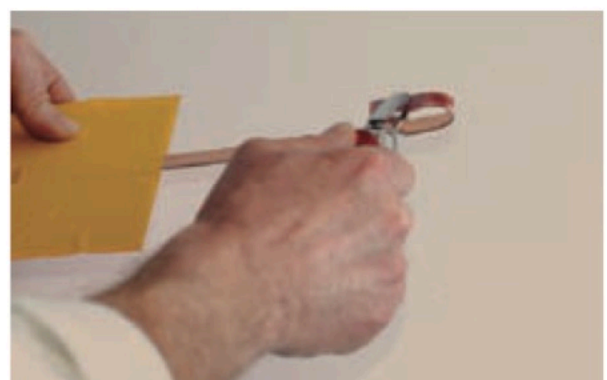
In order to stick the contact-strip to the plate, use a piece of self-adhesive plastic, for example *Fablon*™, a little larger than the plate. Stick the plastic, avoiding air bubbles so that the plate can later be

heated to spread the ink or the soft ground without damaging the plastic with the heat from the hot plate. The plastic also has the function of protecting the back surface of the plate from the electrolytic corrosion. Finally once applied, trim the excess plastic from the edges.

It is important to make sure that the adhesive is of good quality and that it holds the strip to the plate securely. This avoids the risk of the plate becoming detached when it is submerged in the electrolyte and sinking to the bottom of the tank under its own weight.

Steps in preparing the contact-strip.



In order to avoid corrosion of the contact-strip caused by contact with the electrolyte, cover the first few centimetres of the strip beyond the end of the plate with plastic. Finally, bend the end of the contact-strip so that it can be hung from the bar electrodes.

If the plate is large, put two contact-strips on the same side. With these two points of contact and support, the current will flow better and the electrolytic action will be more effective.

When etching, the contact-strip should be hung from the electrode and gripped with a crocodile clip to ensure good electrical contact to give good current flow.

Remember to attach the contact-strip to the plate and cover it before starting to draw the image into the ground on the other side of the plate as doing it afterwards risks spoiling the finished image.

Degreasing the plate

With the contact strip attached and the back of the plate covered, it is time to degrease the front face. Degreasing is a very important stage in the preparation of the plate. Its purpose is to ensure a clean and even bite. Electro-etching as a method is much more sensitive to grease than etching with acids, so that even an accidental fingerprint will not be bitten, leaving a mark on the plate that will be very visible once printed.

When etching open bite areas, a great deal of care must be taken to ensure that these areas are extremely clean and grease-free.

For a plate with line drawings, it should be sufficient to degrease the plate by carefully rubbing the surface with a clean rag or paper towel soaked in alcohol. However, I prefer the following procedure:

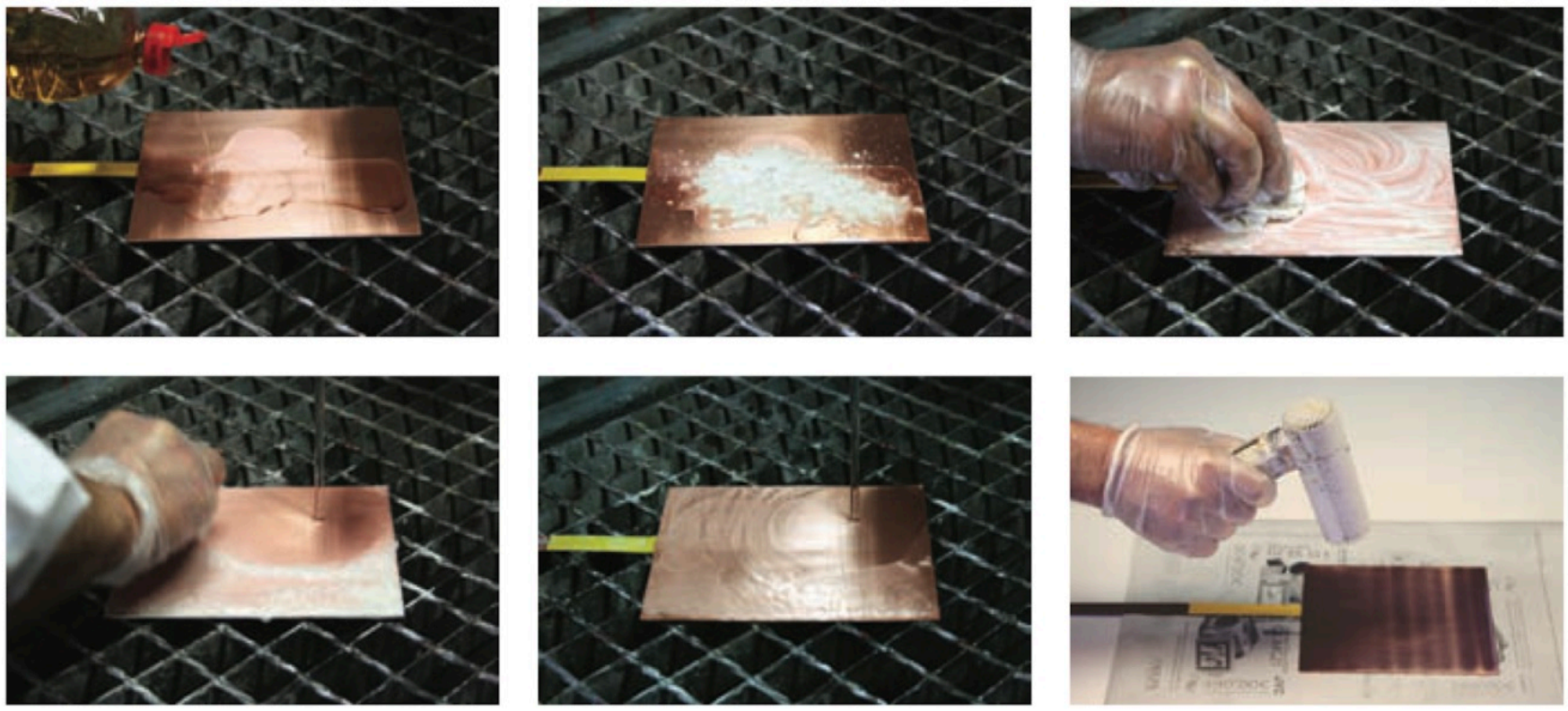
In a deep tray prepare a solution of 1 litre of acetic acid (vinegar) and 80 grams of sodium chloride (common salt). This solution can be kept in a plastic bottle until it is used up. Submerge the plate in a tray filled with the solution for several minutes while rubbing its surface with a soft paintbrush. To finish, rinse the plate with water and dry it with a paper towel or, if you prefer, with hot air.

With an area of open bite, the best way to degrease it is to polish the surface to be etched with a mix of vinegar and whiting (calcium carbonate). Put a teaspoon of the latter on the plate and add a good dash of vinegar. Rub the plate with a linen or cotton cloth, and rinse and dry it as described above. Then, the plate is ready to be covered with a resist suitable for the intended etching work.

An alternative mixture for degreasing uses a recipe of the *Maestro* Sergio de Osio: equal parts of citric acid, in powder form, and

bicarbonate of soda. Put a teaspoon of each on the plate, mix them with a little water and rub with a piece of cloth or paper. Finish by rinsing the plate with water and drying it with a paper towel or, hot air.

Steps in degreasing the plate.



Varnishes or resists

Generally, in electro-etching the same resists or etching grounds are used as in etching with acids: liquid, hard or soft grounds, lithographic crayons, permanent markers, self-adhesive plastic and alcohol varnish, for example. However, there are etchers who are sensitive or allergic to the vapours given off by traditional varnishes, which are usually made by mixing turpentine or petroleum with melted wax and asphaltum dust or rosin. For conventional etching, these etchers do not use these varnishes and have opted to substitute them with acrylic intaglio inks, which block the corrosive action of highly concentrated ferric chloride (*Edinburgh Etch solution*). To date, my experience with these acrylic inks is that they do not work with electrolysis, as a film of ink very quickly builds up on the water in the electrolytic solution, ruining the etching of the plate.

Carrefour's wax varnish for wood. Liquid ground engraver *Ultraflex* and *Duroziez*'s stopping-out varnish, both in the *Charbonnel* line. *Graphic Chemical*'s graphite intaglio ink. Alcohol based glass paint. Lithographic pencils. Soft ground 150. Self-adhesive plastic. Orange oil *Leinos Thinner 200* and *Artools* cobalt drier.

Recently, inexpensive acrylic cleaning products and wooden floor protectors have begun to be used as resists: etchers use them as substitutes for traditional hard grounds. They offer extremely efficient non-toxic resists. I have confirmed that these varnishes can be applied, even if they have a tendency to come off at the edges of the plate after about 20 or 30 minutes of electrolytic action. The manufacturer, *Johnson*, markets a product under a different name in each country: *Future* (USA), *Klear* (UK), *Klir* (France). In addition, I have also obtained some excellent results using some acrylic based grounds, for example, *Lascaux's Hard Resist* and *Lascaux's Stop-out Resist*, particularly for etching needled lines.

Lascaux stop-out resist. *Lascaux* hard resist, *Mystrol* and *Lascaux* remover.

Oil-based intaglio inks made with powder pigments and polymerized linseed oil can also be used very effectively as a ground. These inks are used by modern etchers not only for health reasons, but also because of the versatility this process offers. Now they are even beginning to replace the use of hard and soft grounds and even aquatint and its subsequent melted forms of rosin dust or ground asphaltum, which are considered quite toxic.

Whichever resist is used, my advice is to choose one that is resilient to the effects of the electrolytic action and to apply it to the plate as well as possible: if the resists are not properly spread onto the plate then small pores may be present in the resist so that deep holes or unwanted details will be etched (*foul biting*).

Rinsing tank, washing and disposal of waste liquid

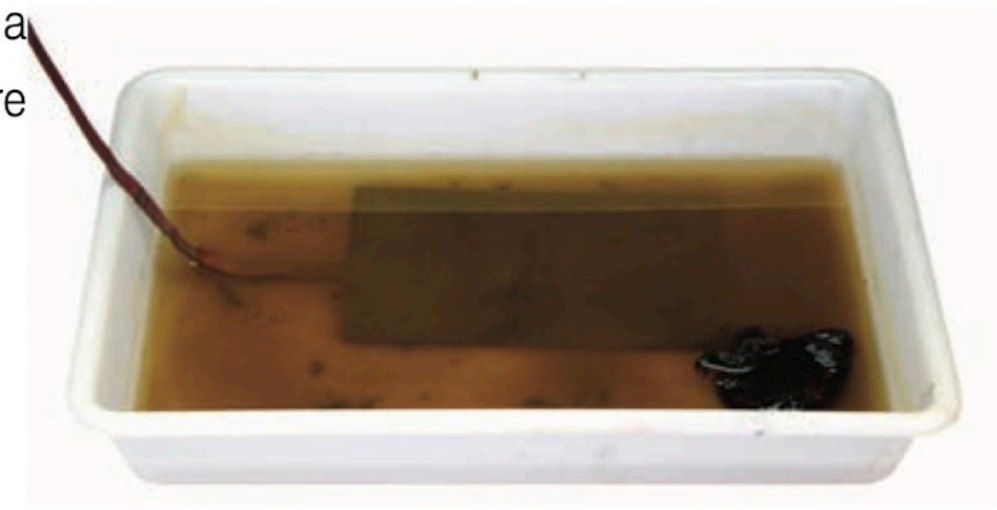
A distinct advantage of electrolytic etching is that the electrolyte does not become exhausted and consequently does not need to be discarded. Further, if when removing the etched plate from the tank the remaining drops of electrolyte are drained back into the tank, then the amount of electrolyte solution to be washed off in the rinse tank –a container filled with water– is minimal.

As stated on their website, Marion and Omri Behr were not only concerned about the possible health issues of traditional etching methods, but also about the environment. By etching copper plates

with electrolysis they have made an environmental contribution because after some easy treatment of copper sulphate solutions in the wash water, it will not affect the aquifers. This may be contrasted with conventional etching where the plates that have been worked on with acid are washed in the sink so that the toxic residues are washed into the aquifers through the drains and sewers. Marion and Omri Behr recommend that plates that have been etched with copper sulphate solution be washed in water with iron filings.

For copper plates prepare a *rinsing tank* which will comfortably accomodate the etching plate, and fill it with water and either clean iron filings free from machine grease, or a piece of fine iron wool for polishing which is sold in hardware shops. On contact with iron filings, copper ions quickly turn into harmless and easily disposable copper particles. The solution in the rinsing tank will turn yellow and, once filtered, can be emptied down the drain (but see comment below). When the plate is removed from the rinsing tank it can be washed with water in the sink. Plates etched in solutions made of zinc sulphate or, ferrous sulphate can be washed in a sink with running water, as these are not noxious.

Iron wool.



Rinsing tank with iron wool for washing copper plates.

Flushing the wash water down the drain may not be a problem but in these days of changing environmental legislation, local disposal regulations should be checked first. Generally educational institutions will have protocols for the disposal of wastewater and chemicals; sometimes these may preclude any flushing down the drain.

Some reminders before starting to etch

It is essential to remember that the electrolyte, the cathode plate (grid) and the contact-strips, must always be of the same metal as the plates to be etched. As indicated earlier in the section *Electrodes and cathode plate* on page 30, the electrodes will be copper.

Do not etch zinc plates in a copper sulphate solution because zinc precipitates the copper ions in the solution and weakens it.

Electrolytic action, that is to say the corrosion of the metal of the plate that is being etched, only takes place when connected to the power supply and the current is flowing between the anode and the cathode. Therefore if we disconnect the power supply, the plate can stay in the tank for some time since the corrosive process will have stopped. The power supply can easily be connected to a timer so that there is no need to keep track of the time because the supply will be switched off automatically after the pre-set period.

Electrolytic processes that use electric energy have the distinctive characteristic of not producing any precipitate or waste in etched lines; one advantage of this is that we do not have to constantly monitor what is happening in the tank and can occupy ourselves with preparing other plates while the electricity is doing its job.

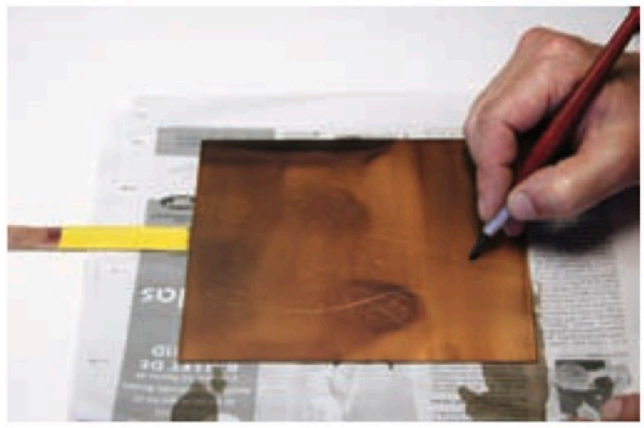
When putting the etched plate in and removing it from the tank care must be taken not to splash the electrolyte: allow the solution to drain from the plate back into the tank. When you wash the plate, do not forget to wear gloves until the electrolyte has been cleaned off. Once the plate has been washed with water and dried, you can then work on it without gloves if you want to continue stopping-out or draw on the varnish again.

Electro-etching lines on hard ground

For a line-drawing made with an etching point or needle there are several hard grounds which can be used as a resist; they work equally well on copper, zinc or iron plates.

Traditional grounds

Some etchers with concerns about the environment and personal safety prefer not to use traditional grounds. If you have no objections to using traditional etching varnishes you can use commercial products such as *Liquid Ground Engraver Ultraflex* or *Lamour's Black Stopping-out Varnish,* both in the *Charbonnel* line. They give satisfactory results. Once the contact-strip is stuck to the plate and it is degreased, *Ultraflex* varnish can be applied cold, spreading it over the plate with a flat soft-haired brush. Once this layer is dry, if necessary, another layer can be applied, making it even more resistant to the electrolytic bite. *Lamour's Black stopping-out Varnish* can be applied as previously described but it should be diluted beforehand with a few drops of turpentine to avoid cracking when drawing. Once dry, the drawing can be made with a variety of etching needles.



Varnishing the plate with liquid ground and, at the side, drawing with an etching needle on hard ground.

Different non-toxic solvents: ethyl alcohol, *Novasol-N*, orange oil *Leinos Thinner 200* and sunflower oil.

If it is intended to bite the drawn lines several times, *Lamour's Black Stopping-out Varnish* can be applied without dilution. It must then be left to dry thoroughly before putting the plate back into the electrolytic bath to re-bite the plate. During etching it is important to keep an eye on the condition of the varnish to ensure that it is continuing to resist the action of the electrolytic bath during long bites: it may start lifting off the plate.

To finish with this etching method, the solvents previously used to remove these varnishes from the plates were turpentine or petroleum

based, which are environmentally unfriendly. For health reasons, Vegetable Cleaning Agent (VCA) is recommended as an alternative for cleaning off inks, rollers, etc., in printing and etching workshops. Any VCA can be used and they are available in most art shops.

Alternative grounds

As I have already mentioned, for non-toxic resists there are two options: acrylic-based or oil-based products.

Acrylic-based varnishes

Acrilyc floor wax hard ground

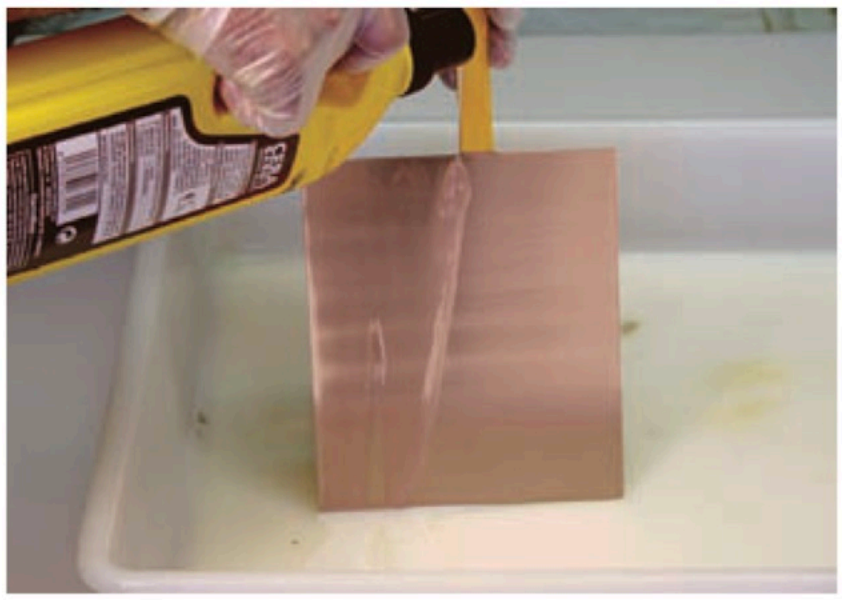
As a cheaper and healthier alternative to traditional etching varnish, acrylic floor wax can be used. It is available commercially as a milky-looking liquid with a consistency similar to Indian ink. It becomes transparent when dry.

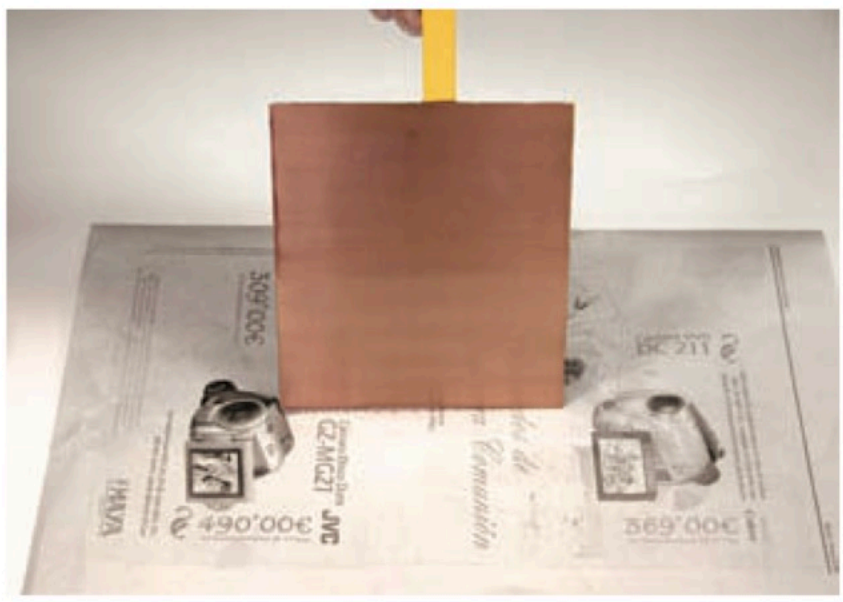
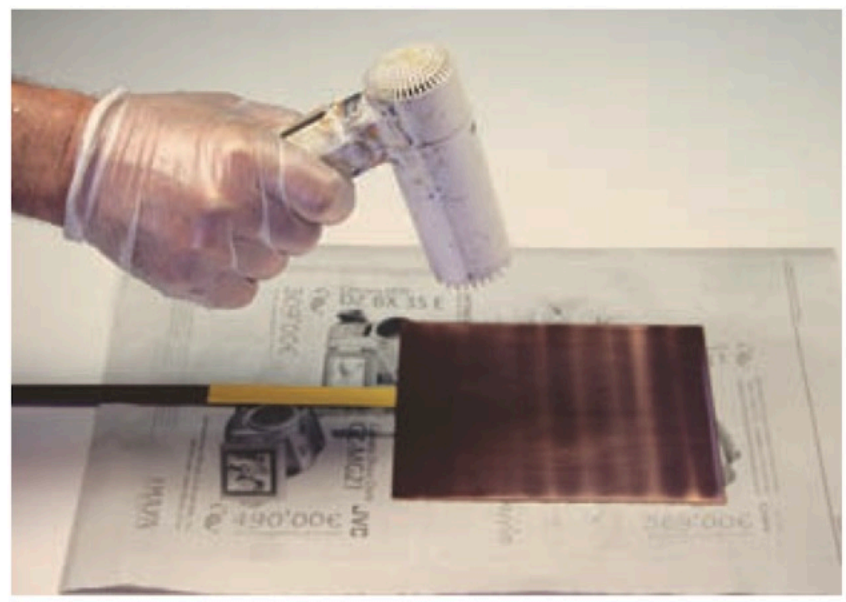
For etching with electrolysis I have used two brands with similar results: acrylic wax varnish for floors by *Johnson* or *Carrefour's Wax Varnish for Wood*. These are transparent and can be mixed with a few drops of Indian ink or tempera (poster paint) to enable the lines that have been drawn on the plate to be visible. Of course, other acrylic varnishes that are appearing on the market can be used.

It is advisable to use latex gloves to protect your hands while applying and removing the varnish to the plate as well as when removing the plate from the tank.

To apply the liquid floor wax, once the plate has been prepared with the contact-strip and degreased, hold it at an almost vertical angle with one hand, letting one of its edges rest on the base of a deep tray. Pour varnish over it with the other hand, covering the plate completely, tilting it and altering its position so that air bubbles do not form. When the plate is covered in varnish, hold it vertically on a piece of newspaper and let the excess varnish drain off. If necessary, rest it on a different side so that the varnish spreads well. Finally, dry the plate with hot air for some 30 minutes.

It is best to apply a second coat of varnish resist, proceeding in the same way as for the first coat. Once the process of applying the varnish is finished, and as long as it is still clean, the varnish that has been collected in the tray can be reused.



Steps in the application of acrylic wax varnish for wood.

When the acrylic varnish is completely dry, it is possible to work on the plate using an etching needle. If the varnished plate has not already been stained with ink or tempera, this should be done first so that the drawn lines can be seen. After this stage the stain should be cleaned off with water to avoid discolouring or clouding the electrolyte when the plate is immersed in the bath.

Stop-out acrylic varnish

When biting (etching) a plate for different lengths of time a stop-out varnish is required. This is easily prepared using the acrylic varnishes and the following recipe by Paco Mora:

1 part Johnson's or *Carrefour's Wax Varnish for Wood*

1 part binder such as *Lascaux Transparentlak* 2060, or *Primal acrylic resin*

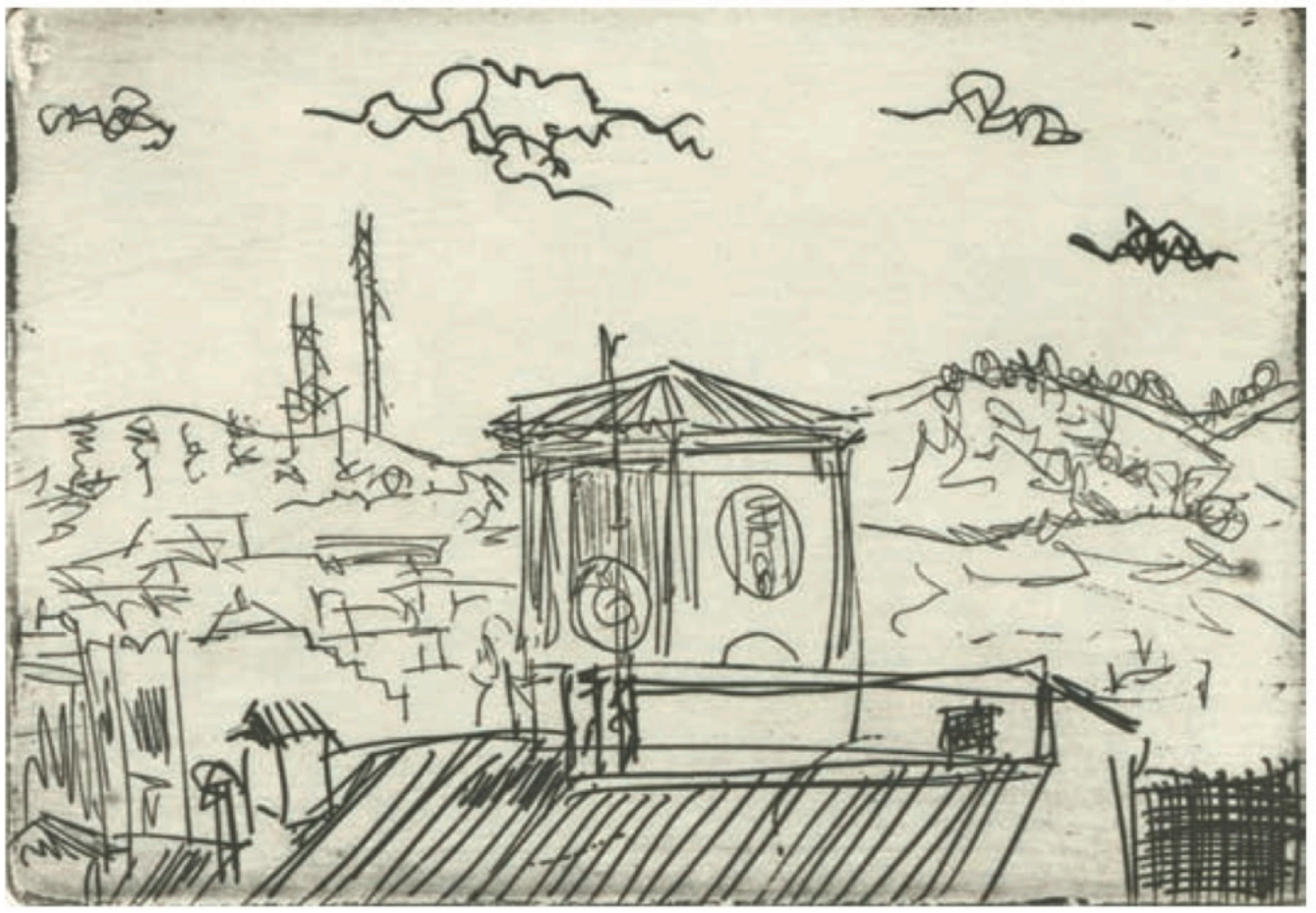
1 part acrylic paint

Remember that when the stop-out has been used on the plate, it is best to dry it properly with hot air before beginning to draw on the plate or etching it.

Removing the acrylic hard ground from the plate

The coat of varnish is very resistant, so to remove it from the plate it has to be submerged in water with a high sodium carbonate concentration (washing soda), or in an ammonia solution (a domestic cleaning product containing ammonia applied directly onto the plate). If the varnish is very difficult to remove, isopropyl alcohol (dimethyl carbinol), which is sold in pharmacies can be used.

After the etching is finished, some etchers make prints without removing the varnish from the plate. This is for each individual to decide.



Copper plate. *Carrefour Wax Varnish* resist. Lines drawn with etching point. Concentration of 250 g/l. Voltage 0.5 V. Two intervals in bites of 10 mins and two of 15 mins. Made with stop-out acrylic varnish.

Acrylic liquid hard and stop-out resist

The liquid acrylic-based varnishes available under the *Lascaux* brand, mentioned earlier, can be used as hard ground for electrolysis. *Lascaux's Hard Resist* is a liquid resist which can be applied on the degreased plate with a flat, soft paintbrush. It dries in 15 or 20 minutes without applying heat. While one well-applied coat of varnish is usually sufficient, there is no harm in applying a second coat to be on the safe side. The varnish can take long bites and is suitable for etching all types of lines.

If it is desired to bite the drawn lines several times then *Lascaux's Stop-out Resist* can be used to cover those areas not requiring further

biting. It should be left to dry properly between successive bites in the electrolytic bath. *Mystrol*, an acrylic etching grounds remover, can be used to lift these acrylic varnishes from the plate. In a deep tray put enough *Mystrol* to cover the plate. Submerge the plate and the layer of varnish will lift off easily after a few minutes. This *Mystrol* can be reused if it is filtered through a fine strainer but it should be stored in a separate container from unused *Mystrol*. Of course, *Lascaux Remover*, may be used although it is somewhat more expensive than *Mystrol*. These varnishes can also be removed with ethyl alcohol. I hope that eventually we can find ways to remove them with cheaper, non-toxic products.

Oil-based hard varnishes

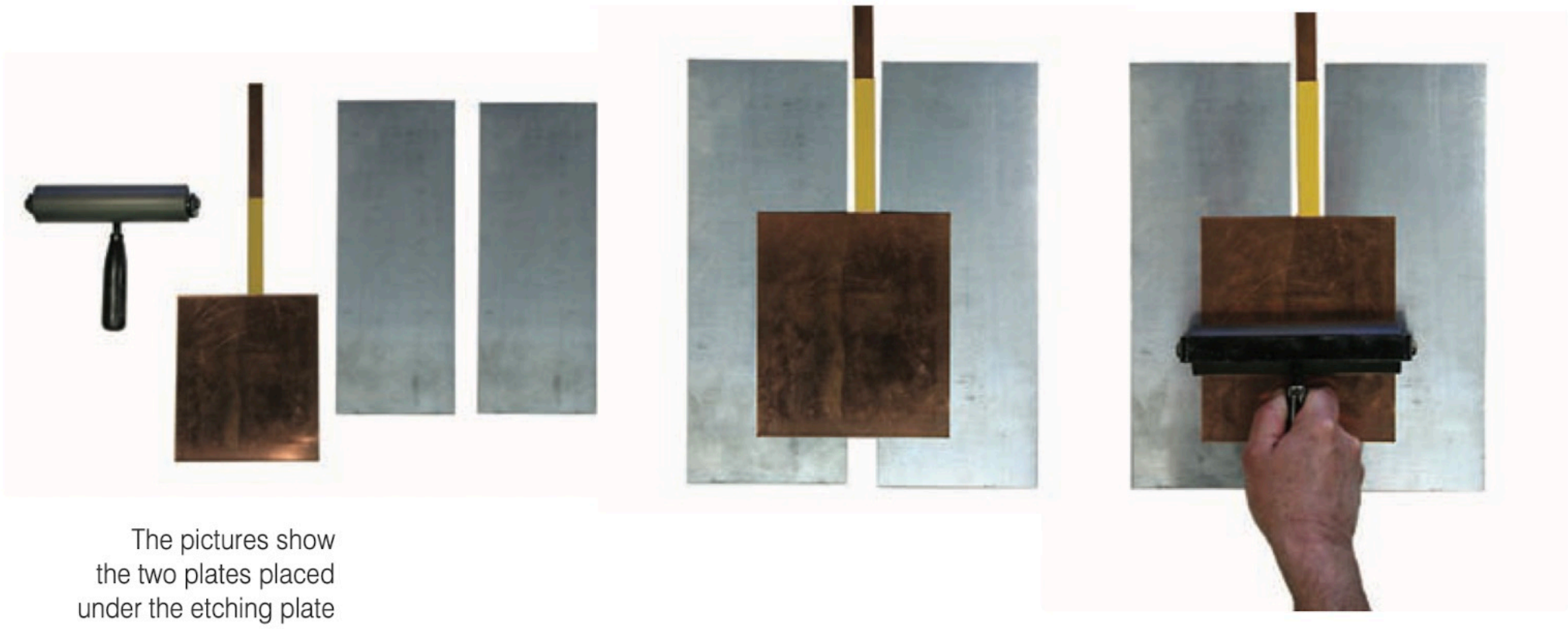
Intaglio inks made with pigment and linseed oil can be used as resists. This formulation is non-toxic, but it dries more slowly. In my work I have used several brands of ink with varying results.

Intaglio ink hard ground

Any brand of ink can be used. I have used *Loriellеux* or *Charbonnel Intaglio*, usually black. To prepare the ground, use a spatula to take a small amount of very clean ink that does not contain any hardened particles. Put it on the inking marble and dilute it with a little pure linseed oil and a few drops of cobalt drier so that it will dry more quickly once applied. Mix the ink well, giving it the consistency and viscosity used for printing linoleum –test to ensure that the correct consistency has been achieved for your specific purposes.

Load the ink on a roller of medium hardness and spread it on the marble. Once the plate has been prepared with the contact-strip and degreased, spread the ink on the plate with the roller, taking care that the layer of ink is even. Make sure that there are no open pores left in the film of ink so that the resist will be opaque to the bite. To avoid such pores you can load the roller again and roll it over the plate. It is advisable to offset the depth of the contact-strips, so that the roller can be used on a flat and stable surface. To do this, place two flat plates of the same thickness as the contact-strip underneath the etching plate. Next, the plate needs to be dried: leave it in a well-ventilated area for

two hours or even on a hot plate in order to accelerate the process. Alternatively, the plate can be left to dry in the sun.



The pictures show the two plates placed under the etching plate to counteract the depth of the contact-strips in order to stabilise it and spread the resist evenly.

Once dry, the ink ground can be worked on with different etching points. Drawing on the ink with a paper blending stump or *torchon* soaked in alcohol can give interesting effects, although this is best done before the ink has dried. Glass paint (alcohol-based) may be used as a stop-out resist.

Products: *Graphic Chemical*'s graphite ink; orange oil *Leinos Thinner 200*, a non-toxic cleaning agent used at Atelje Larsen to dilute the inks and clean the plates and tools; cobalt drier; and glass paint.

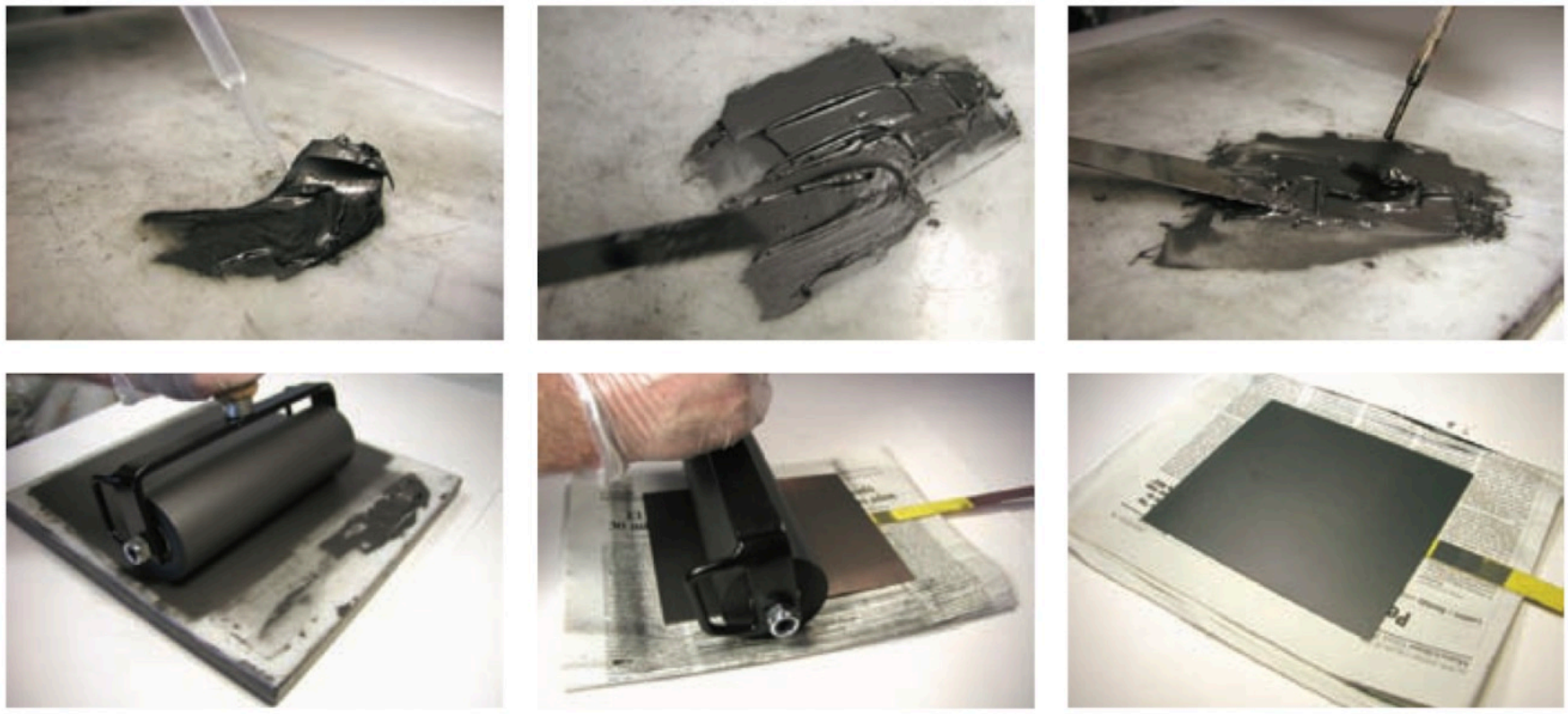
After etching, the ink should be removed from the plate with a vegetable cleaning agent or ethyl alcohol. If the ink is stuck fast to the plate, a little acetone can be used, preferably in a well-ventilated area of the studio. Finally, the plate must be washed thoroughly using soap and a soft-bristled brush.

Graphite intaglio ink hard ground

As with ordinary intaglio ink, this is also a non-toxic alternative to traditional etching grounds. This is the method practiced at Atelje Larson. *Graphic Chemical*'s graphite intaglio ink nº 2326C is used and diluted with a few drops of orange oil *Leinos Thinner 200*, to give it the right viscosity, and a few drops of Artools cobalt drier, to speed up the drying process. The reason that orange oil is used instead of

cheaper linseed oil is that I have not managed to get the required characteristic effects of this recipe when mixing the graphite ink with other thinners. This will become clear when the electrotint process with this ink is explained –see section *Electrotint with a graphite ink mix* on page 67.

The preparation process is the same as for traditional intaglio ink, but using the products just mentioned. With a clean spatula mix the graphite ink on the inking marble, free from any hardened particles, with a few drops of orange oil (as much as necessary to give it sufficient viscosity to spread with the roller). I should point out that getting the ink to the correct consistency is a question of experience. Finally, add a few drops of cobalt drier, mix well and load the roller with ink on the marble.

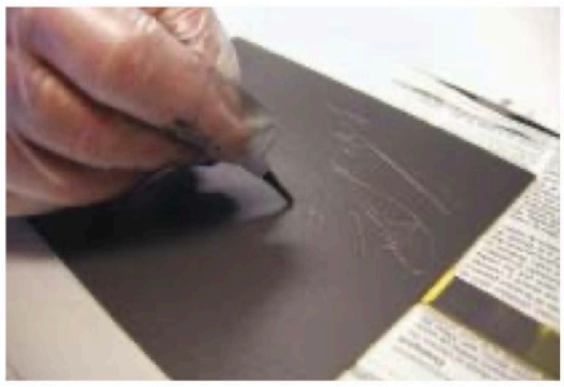


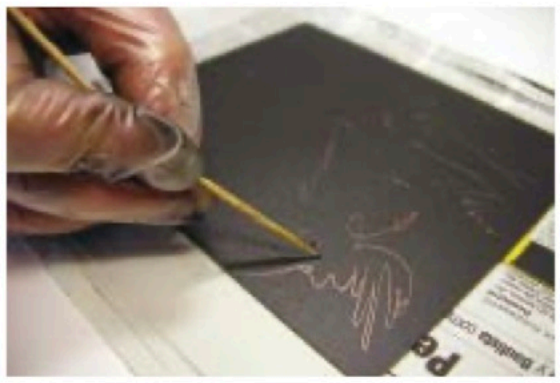
Images of the sequence of steps used in the process.

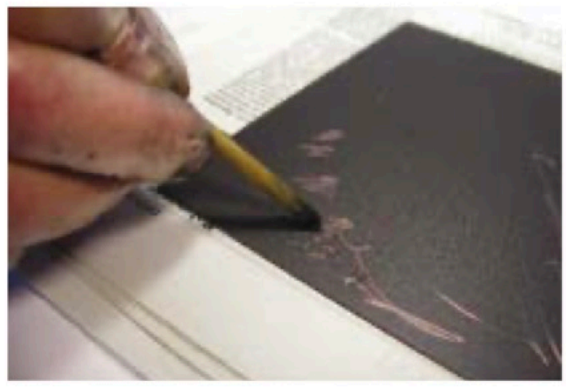
Use the roller to spread the ink on the plate that has already been prepared with the contact-strip and degreased. Roll the ink on the plate until there is an even, opaque layer, so that it will be resistant to the bite. Next, leave it to dry thoroughly on a hot plate set at moderate heat for approximately one or two hours.

The electrolytic bite on the layer of graphite ink ground has different effects on each of the metals (copper, zinc or iron) used for etching. However, the etching method that I am detailing is applicable to any of these metals. On ground that is still damp, it is possible to

work with gravers or needles of all types, thick and thin, metal, wood or plastic. With this method a great variety of lines can be achieved –perfectly formed fine, narrow lines or wide and deep– without producing *crevés* in the widest etched lines. This is a unique characteristic of this graphite ink.







The pictures show different techniques of drawing on the plate: with an etching point, with one of wood for drawing thicker lines and, using a point made with a reed to draw the thickest lines.

Working on dried graphite ink ground with etching needles can produce, fine, delicate lines in your work. You can explore all the variations that this technique offers through experimentation. An alcohol-based varnish or glass paint that does not melt with heat can be used as stopping-out varnish. They are both soluble in ethyl alcohol, which can be used to lift them from the plate after etching. Orange oil *Leinos Thinner 200* can be used as a solvent for graphite ink to clean the plate after etching.

Sometimes, the ink can be stuck so firmly to the plate that, until now, it has proved best to remove the most resistant ink with a cloth soaked in acetone. This should be done outside in the open or in a well-ventilated area of the workshop.

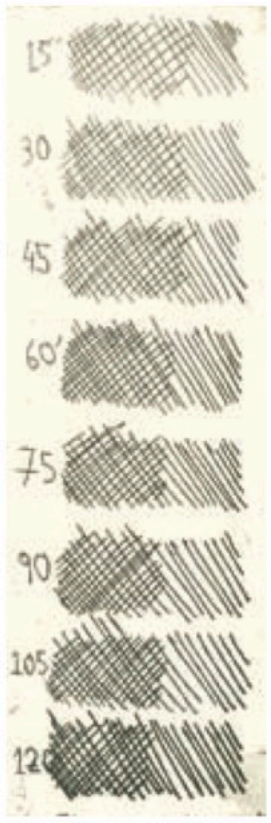
Recently, I have discovered that the *Novasol-N* brand of vegetable cleaning agent –an environmentally friendly solvent used in printing workshops– is able to remove dried graphite ink more easily than the methods above.

Electrolytes, voltages and bite times

Once the plate has been prepared and drawn on, using whichever resist you prefer, place the plate in the electrolytic tank, connecting it to the positive electrode which will be positioned in parallel to the negative electrode. You will have already put an electrolyte with the appropriate concentration for the job in the tank.

Etching lines on copper plates

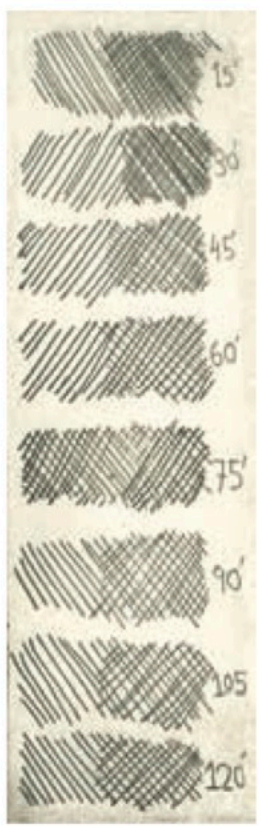
The copper sulphate electrolyte can have a concentration of between 160 g and 250 g/litre of water and a voltage of 0.5 V should be used.



Test strips etched on copper plates.
Ultraflex Charbonnel varnish resist and electrolytes of different concentrations and voltages bitten at 15 minutes intervals.
From left to right:
250 g/l - 0.5 V;
250 g/l - 1.0 V;
160 g/l - 0.5 V.

Etching lines on zinc plates

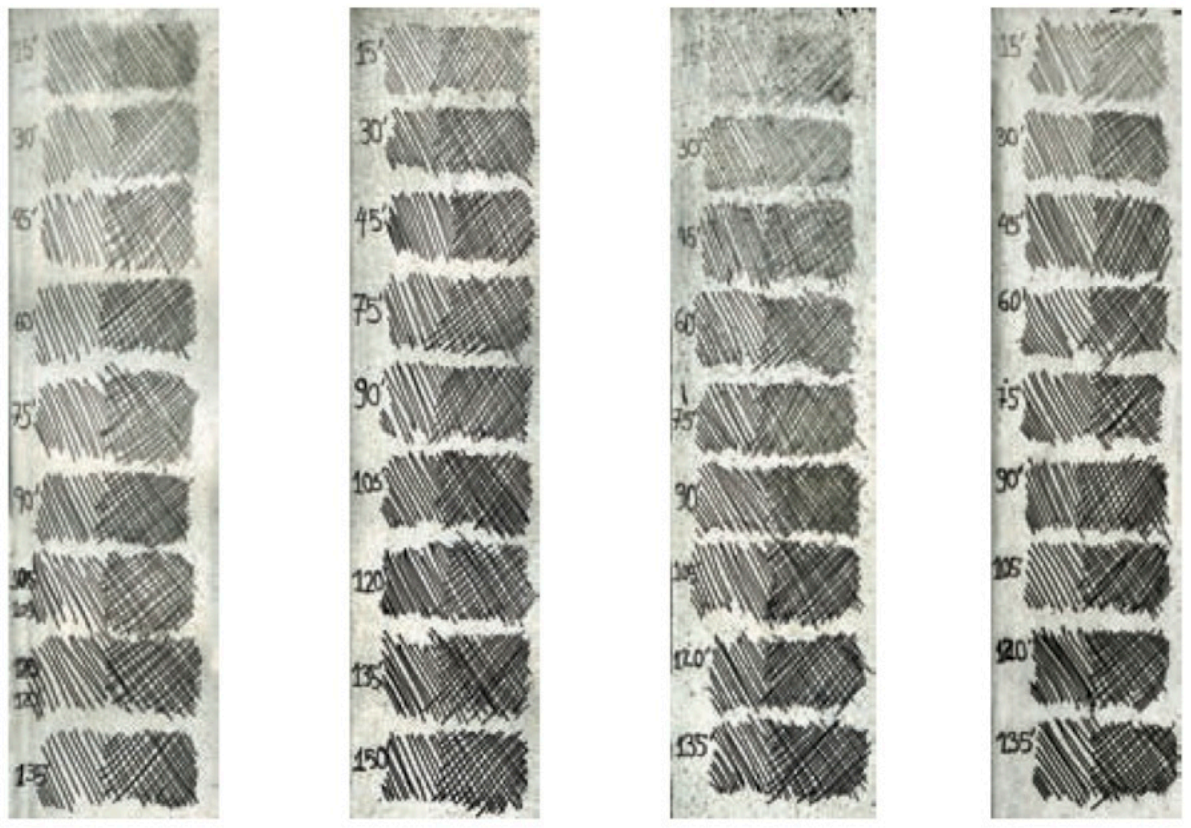
I have obtained good results experimenting with electrolytic solutions of different concentrations of zinc sulphate, ranging between 160 g and 300 g/litre of water. Also, a concentration of 500 g/litre of water allows acceptable quality etching over shorter periods of time. A voltage of 0.5 V is large enough.



Test strips etched on zinc plates.
Ultraflex Charbonnel varnish resist and electrolytes of different concentrations and voltages bitten at 15 minutes intervals.
From left to right:
160 g/l - 0.5 V;
225 g/l - 0.5 V;
300 g/l - 0.5 V;
300 g/l - 1.0 V;
500 g/l - 0.5 V.

Etching lines on iron plates

The concentration of ferrous sulphate electrolyte used ranges from 200 g to 250 g/litre of water. The voltage can be between 0.5 V and 1 V.



Test strips etched on iron plates. Electrolytes of different concentrations and voltages bitten at 15 minutes intervals. From left to right: 200 g/l - 0.5 V; 200 g/l - 1.0 V; 250 g/l - 0.5 V; 250 g/l - 1.0 V.

The times given for electro-etching lines on these metals should be ample. From 15 minutes onwards we can get printable lines, but I advise doing a test plate with a series of separate needled lines together with cross-hatched lines for any of these grounds. In order to familiarise yourself with the process and calibrate the system, start with an electrolytic solution of 160 g/litre of water, a voltage of 0.5 V, biting at intervals of 15 minutes up to, say, 120 minutes. Afterwards, if your power supply is able to provide sufficient volts and amperage, you can test using more concentrated solutions.

Step biting

For repetitive bites it is important that the furrows that will be re-etched are kept clean. So first of all, between bites those parts of the plate which do not require re-etching should be covered using a stopping-out ground as a resist.

This resist should be allowed to dry completely. Then the plate should be placed in a tray with a degreasing solution of salt and vinegar –see section *Degreasing the plate* on page 45 to clean the open furrows that will be etched again.

Characteristics of the electro-etch "bite"

One of the advantages of electro-etching is the type of line that this method produces. Acids tend to bite in all directions and can eat away at the metal of the plate beneath the resist. Furthermore, they can even cause the edges of the resist to peel off if the bite is deep. By contrast, the electrolytic bite remains perpendicular to the surface of the plate –this is the reason it produces cleaner furrows– and the parts of the plate beneath the edges of the resist are not corroded.

ACID BITE ELECTROLYTIC BITE

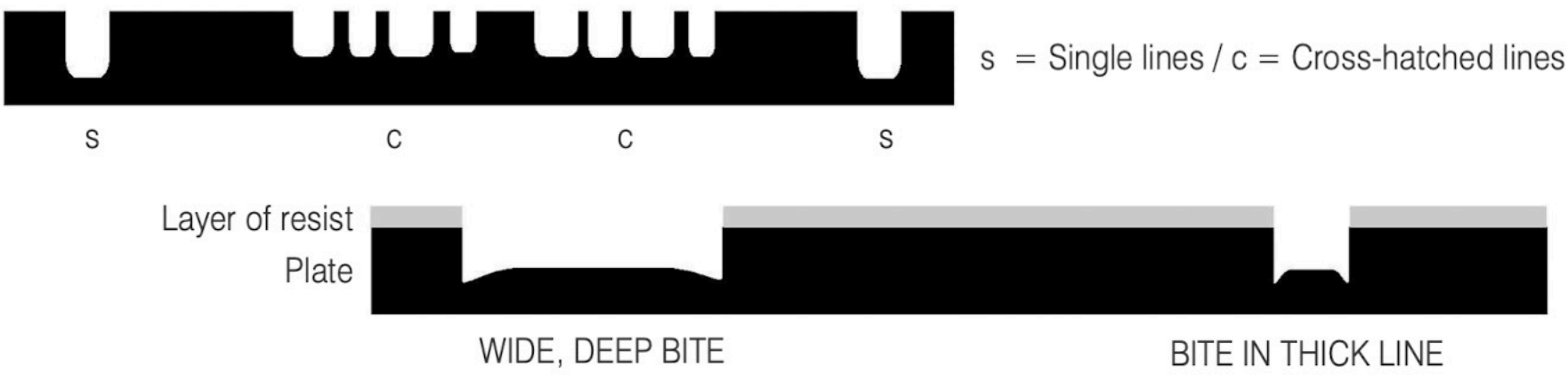
The illustrations show the difference between corrosion with acids and the electrolytic bite.

Another unique characteristic of electro-etching is that a drawing with closely cross-hatched lines does not have the tendency to lose the definition of the individual lines and cause *crevés* (which do not hold the ink) because of the gradual merging of the lines. We can etch at low voltage for long periods of time and get fine and heavy lines, or deep and shiny lines with clean edges, without the ground peeling away.

ACID BITE ELECTROLYTIC BITE

However, there is also a drawback: the *edge effect* (see page 32) which has the tendency to bite isolated lines more than those close together or cross-hatched. It can also be observed that the electrolytic action acts with greater intensity at the edges of the resist of broad lines and on the broad surface of an open bite. In spite of this, the disadvantages are not significant when compared with the advantages.

The following illustrations show the difference in depth of the electrolytic bite due to the placement of the line and the effect of the bite on the edge of the resist.



Characteristics of the electro-etch on graphite ink

If you have used the recipe for graphite ink as a hard ground and want to work on a line drawing, my advice is to first carry out a test plate with simple lines and cross-hatch, biting it at intervals of 15 minutes, up to 120 minutes in total, with any of the following electrolyte concentrations:

- The concentration for copper plates will range between 200 g and 250 g/litre of water, with a voltage of 0.5 V.
- The concentration for zinc plates will range between 200 g and 300 g/litre of water, with a voltage of 0.5 V.
- The concentration for iron plates will range between 200 g and 250 g/litre of water, with a voltage of 0.5 - 1 V.

Etchings on copper plate, graphite ink resist, lines drawn with different points. On the left, 200 g/l - 0.5 V - 60 mins. On the right, 250 g/l - 0.5 V - 60 mins.

Etching on zinc plate, graphite ink resist, lines drawn with different points, 300 g/l - 0.5 V - 60 mins.

When working on damp graphite resist with needles and etching points of different thicknesses, as I have already described when I explained this technique*, etching can be undertaken with any of the solutions to obtain fine or heavy lines with a single bite. To do this, once the drawing is

* See page 55.

finished and the resist is completely dry, etch the plate in the electrolytic bath for 60 minutes, without using successive coats of resist. It's a very interesting, but also, an experimental method.

Etching on iron plate, graphite ink resist, lines drawn with different points. On the left, 250 g/l - 0.5 V - 90 mins. On the right, 250 g/l - 1.0 V - 90 mins.

Electrotint

The discovery of aquatint in France in the 18th century endowed intaglio printing with a unique means of expression. This method rapidly spread throughout the printmaking world and has survived to this day as an effective and controlled method for creating tonal areas ranging from greys to deep blacks. Of course, any printmaker knows the process of traditional aquatint. We know that applying the rosin or asphaltum dust on the plate creates a pattern of small isolated dots. Once the rosin dust is melted, the acid will corrode the exposed metal areas between them and create, with the help of stop-outs, tonal effects of different intensity.

Electrolytic action on an open area of the plate gives rise to a stippled matt surface on the bare metal that, when printed, produces a tone similar to aquatint.

Marion and Omri Behr have named it *Microtint*®, Cedric Green calls it *Galv-tone* because, for him, it's more like a flat, deep and even

tone. As I have already mentioned, none of them uses toxic resin dust or ground asphaltum, or their subsequent melted forms, to obtain tonal areas on their plates. Together with these etchers and investigators, I recommend taking advantage of this property to substitute the effect of traditional aquatint.

If you wish, rosin dust and asphaltum to mask the plate can be used to generate the aquatint effect, but the rosin may peel off the plate during electrolytic action. To avoid the latter, electro-etch for a few minutes of open bite the areas where the dust of rosin or asphaltum will be applied.

However, the challenge is to not use these toxic dusts, sprays and liquids: the etching workshop is a new space after removing pungent acids, rosins and solvents.

An open area of metal that is subjected to electrolytic action produces, depending on the type and micro-structure of the metal used, a so-called *electrotint** or an electrolytic pattern of *micro dots* generated on its surface. This retains the ink, and achieves a variety of grey tones, which are made more, or less, intense with the help of stop-out grounds. This method can be used on a plate that has previously been etched with lines or on a blank plate, when the aim is to create tonal areas first. Once the plate has been prepared with the contact-strip and degreased, proceed as if the rosin had already been applied and melted onto the plate. Start by covering the areas that are to print as white with a suitable resist and apply electrolysis in different stages of resists and bites. In this way, by protecting areas and applying electrolysis for short periods of time, the tone of any image can be subtly darkened.

* After long discussions with Bob Perkin we decided to use electrotint to describe this granulated surface of electrolytic micro dots that retains the ink.

A series of short bites superimposed on an open area will gradually darken the tone much better than a single long bite directly on the same area.

Masking techniques

You can experiment using different types of masking techniques, for example, splashes and drops of liquid resist, flicking resist with a toothbrush or stencil brush, and consecutive bites on the bare areas of the plate.

Applying oil-based grounds, such as lithographic pencils or wax bars, give bright lines that, although very resistant, will lift during electrolysis and create interesting graded tonal effects. Another way of using these pencils as resists is to draw a cross-hatch and bite it in successive stages of resist and bite. Even permanent markers can be used as resist. Another option is to put sand or sugar on damp varnish and either press them in manually, or pass the plate through the press, protecting the felts with a plastic sheet. Once it is dry, brush off the grains before electro-etching.

In open bite the tone can be darkened even further by allowing the electrolyte to dry and crystalise on the area of open bite and leaving this to oxidise for some time before continuing with another bite.

I know from experience that this type of open bite etching does not deliver the even, controllable tone produced by aquatint obtained with rosins and acids, which provide impeccable areas of pure, even tone. In my opinion, for the time being, this *electrotint* generated on the metallic surface by an open bite is no substitute for traditional *aquatint*. However, in this handbook I will try to provide some alternative processes to aquatint. Bear in mind that the electro-etching "bite" does offer a very interesting field of exploration.

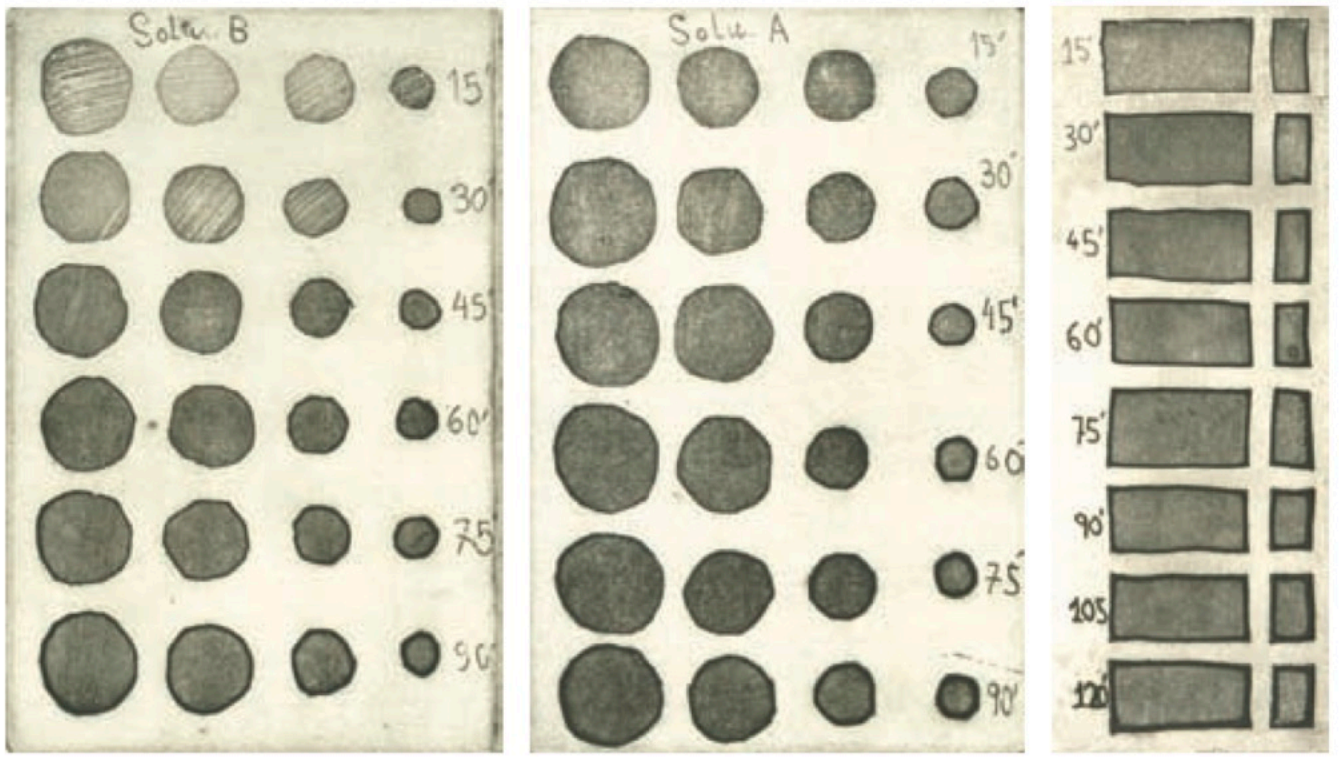
I am convinced that with the combination of the micro dots produced by electrolysis and the application of your knowledge acquired from traditional etching processes (especially the different methods of blocking and stopping-out to resist the action of the acid) electro-etching will provide you unexpected creative satisfaction. At the same time, and almost without being conscious of it, your workshop will be freed from the undesirable gases and fumes, to which, unfortunately, we are accustomed. Simply put, it will change the atmosphere in your workshop thus reducing the health risks involved in the etching process.

Electrolytes, voltages and bite times

To generate these unique micro dots the same electrolytes previously mentioned, but with different concentrations and voltages, can be used. My conclusions are summarised below.

Electrotint on copper plates

The concentration of the copper sulphate electrolyte will range between 160 g and 200 g/litre of water, and a voltage of 0.5 V should be used.

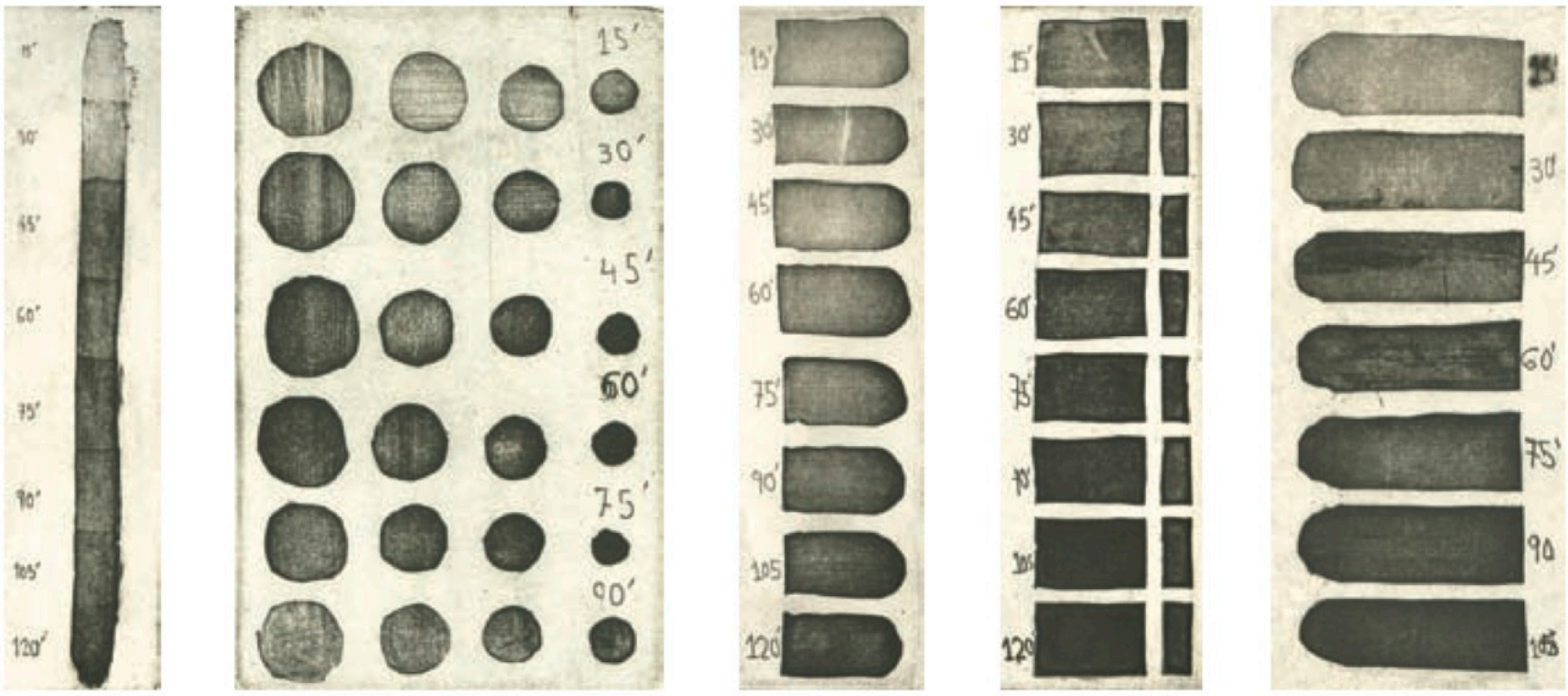


Electrotint test strips with open bite, etched on copper plates, bitten at 15 minutes intervals. From left to right: 160 g/l - 0.5 V; 200 g/l - 0.5 V; 250 g/l - 1.0 V. On the first test you can see the marks left by using alcohol to degrease the plate.

On copper plates electrotint produces a whole range of shades from a variety of greys to the darkest, most intense tones, using low concentration solutions at low voltage. A voltage of 1 V does not generate more intense micro dots.

Electrotint on zinc plates

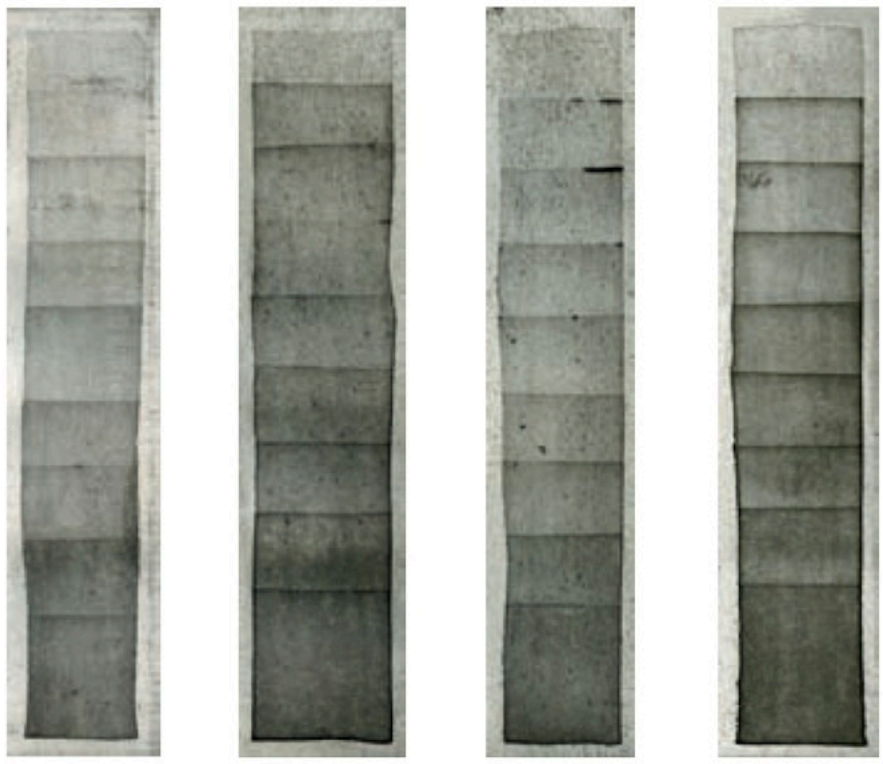
Lines can be etched on zinc plates with zinc sulphate electrolytes at low concentrations ranging between 160 g and 250 g/litre of water, using a voltage of 0.5 V. However, for producing electrotint, higher concentrations are preferred: a concentration of 300 g/litre of water at 0.5 V generates more intense micro dots than the lower concentrations as used for line work. This same concentration and a voltage of 1 V produce an even more intense effect. A concentration of 500 g/litre of water at 0.5 V also produces a rather interesting electrotint.



Electrotint test strips with open bite, etched on zinc plates, bitten at 15 minutes intervals. From left to right:
160 g/l - 0.5 V;
200 g/l - 0.5 V;
300 g/l - 0.5 V;
300 g/l - 1.0 V;
500 g/l - 0.5 V.
On the second test you can also see the marks left by using alcohol to degrease the plate.

Electrotint on iron plates

The concentrations of ferrous sulphate electrolyte will range between 200 g and 250 g/litre of water, using a voltage of 0.5 - 1 V. High concentrations and a voltage of 1 V generate a darker tone of electrotint on iron.



Electrotint test strips with open bite, etched on iron plates, bitten at 15 minutes intervals. From left to right,
200 g/l - 0.5 V;
200 g/l - 1.0 V;
250 g/l - 0.5 V;
250 g/l - 1.0 V.

Spit bite

The traditional effect of spit bite uses a plate that has been prepared for aquatint. However, instead of immersing the plate in an acid bath, the acid is painted directly onto the plate to obtain a “looser, painterly” aquatint effect. Usually the acid must be applied a number of times since the small amount that is painted on is much less effective than an acid bath.

To achieve a similar effect of spit-bite on zinc and iron plates –without the use of rosin or asphaltum, a solution of copper sulphate with a concentration of 250 g/litre of water can be used. After stopping out any areas you do not want to etch, apply the solution directly onto the bare metal of the plate with a paint brush or a cotton bud. Use a face mask and gloves for protection. Electro-etching is not required for this process.

Electrotint with a graphite ink mix

One of the particular characteristics offered by the application of graphite ink is that it produces a very special electrotint, particularly on copper plates. On zinc and iron plates it does not achieve exactly the same effect, although you can also experiment on these metals and obtain no less interesting results.

Once you are familiar with this technique and have learnt how to control it, you can etch both lines and electrotint in a single bite, which leaves the plate ready for printing (after cleaning).

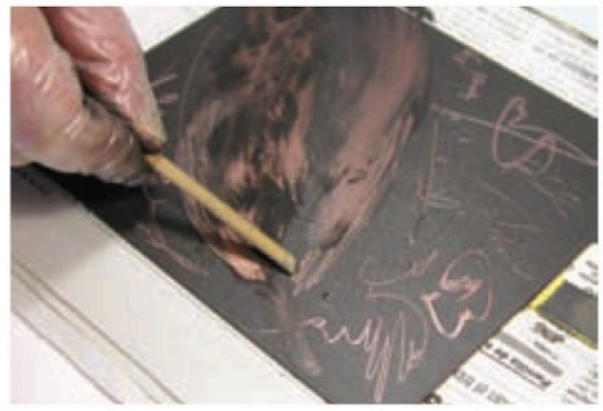
As indicated earlier in the section *Graphite intaglio ink hard ground*, start by mixing the graphite ink with a little orange oil *Leinos Thinner 200* until the correct viscosity is obtained to spread it with the roller. Add a few drops of *Artools* cobalt drier and mix it in well. Next cover the plate with the resist: using the roller, spread the ink on the plate (previously prepared with the contact-strip and degreased). It is very important to cover the surface completely, if necessary rolling in different directions a number of times to ensure that the layer of ink will be sufficiently opaque to the bite in order to get pure white areas where required.

To obtain areas where texture can be formed to give varying tones and effects, the ink must be thinned out with orange oil in these regions. There are two ways to proceed.

Method 1

On graphite ink that is still damp, draw the necessary image lines with metal points, sharpened wooden sticks, etc. Then, on those areas of the plate where you wish to create electrotint, dilute the ink with a little orange oil *Leinos Thinner 200* and if required work these areas with different tools –brushes, cloths, paper, cotton buds or a torchon, dry or soaked in orange oil, to obtain different marks and textures.

Steps for using graphite ink to produce electrotint.
From left to right:



Bear in mind that this mixture of graphite ink and orange oil acts in the same way as when the plate is protected with litho-graphic pencils or wax bars. The thicker the layer of wax (or ink, in this case), the whiter the area covered by the resist will be; the less opaque layers will create a range of grey tones, right up to the very darkest. You should also be aware that to obtain these darkest tones it is necessary to leave a very fine film of orange oil with hardly any graphite ink.

Spreading the ink on the plate, diluting it with a little orange oil and the help of a brush; dried and spreading the oil with paper; drawing with a wooden stick (you can see the areas of exposed metal where micro dots will be generated); textures obtained with oakum thread as a soft ground; copper plate ready to etch and the print obtained after applying the following electrolytic bath: 200 g/l - 0.5 V - 60 mins. On the left, etching on copper plate and electrotint with graphite ink. Method 1: 200 g/l - 0.5 V - 60 mins.

When the drawing and thinning of the ink to create areas of electrotint are finished, dry the ink and oil thoroughly on the hot plate at moderate heat before using the electrolytic bath. This procedure can be complex if you do not keep a close eye on the unusual effects produced by the mixture of graphite ink and orange oil. I recommend that you take time to play and experiment with this technique at your leisure. The results will be a surprise: really rich and bright printable tones and textures can be obtained with a single bite.

Method 2

This method requires at least two steps. It may be a simpler introduction to handling graphite ink, but it is no less expressive because of this. Many etchers use it as a more easily controllable alternative so that they can develop the expressive qualities obtained by using this ink as resist.

Once the plate has been prepared as outlined above, apply an even layer of the graphite ink mixture with a roller. Then, with the ink still damp or dry (depending on your preference) draw lines and strokes, as if it were a hard ground or a soft ground. Leave it to dry, bite it for the required time and, after removing the ink, it can be used to make a trial proof. Now proceed to the second step.

- Prepare the plate again with the contact-strip and degrease it
- The areas that you do not wish to etch further will now be protected with glass paint, alcohol resist, or self-adhesive plastic –oil or acrylic based stop-out is not used since they will mix with the graphite ink and they would melt while drying on the hot plate. Leave the resist to dry
- With a roller, brush or any tool of your choice, apply the mixture of graphite ink, orange oil and drier
- Now begin thinning the ink layer with orange oil to create areas which can be electrotinted with further etching as outlined in method 1. Once again we can obtain different tones of greys and blacks due to the micro dots produced. Dry the graphite ink on the hot plate before introducing the plate in the electrolytic tank and bite it for the required time.

Of course, the plate can be etched by successively protecting and biting the plate for shorter periods of time depending on the characteristics of your work.

Etchings on copper plates and electrotint with graphite ink. Method 2: after first etching of lines, on the left, 200 g/l - 0.5 V - 60 mins + 60 mins. 1st stage proof see picture (left) on page 61. On the right, 200 g/l - 0.5 V - 60 mins + 90 mins. 1st stage proof see picture (right) on page 61.

Electrolytes, voltages and bite times

Electrotint with graphite ink on copper plates

Use an electrolyte of copper sulphate with a solution of 200 g/litre of water at 0.5 V for 60 minutes.

Electrotint with graphite ink on zinc plates

Use an electrolyte of zinc sulphate with a solution of 300 g/litre of water at 0.5 V for 60 minutes.

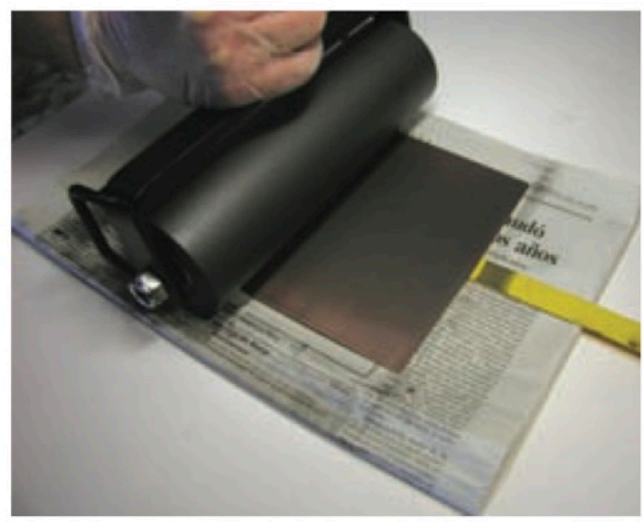
Electrotint with graphite ink on iron plates

Use an electrolyte of ferrous sulphate with a solution of 250 g/litre of water at 1.0 V for 60 or 90 minutes.

A variation of the above technique using the same recipe –graphite ink, orange oil *Leinos Thinner 200* and cobalt drier– can give a range of greys stretching across the plate. The roller loaded with a small amount of the mix of graphite ink is used to spread an even layer of ink mix to give a matrix of small ink dots on the bare metal of the plate where electrolysis will take place (in essence this is similar to

the matrix of melted rosin dots on a traditional aquatint plate). The matrix will depend on the viscosity of the ink, the hardness of the roller and the thickness of the layer of ink. A foam roller can also be used.

Etchings of lines and electrotint with graphite ink. Method 2: on the left, copper plate, 200 g/l - 0.5 V - 60 mins. On the right, zinc plate, 300 g/l - 0.5 V - 60 mins. 1st stage proof see picture (below) on page 61.



From left to right: Etching on iron plate and electrotint with graphite ink. Method 2: after the first etching of lines. 200 g/l - 1 V - 90 mins. 1st stage proof see picture (left) on page 62; etching on iron plate and electrotint with graphite ink. Method 2: after the first etching of lines. 200 g/l - 1 V - 60 mins + 30 mins. 1st stage proof see picture (right) on page 62. The picture on the left shows the application of a porous layer of graphite ink with a poorly loaded roller.

After these dots have been dried with heat and the plate electro-etched for about 15 minutes, another layer of ink can then be applied in the opposite direction to the first layer to even up the pattern. This will leave a distribution of dots that, if controlled properly, will also give the effect of a darker electrotint.

Please accept my apologies if the description of this interesting method of applying graphite ink appears to be complicated, but there is no secret to it. Furthermore, in the different sections of this manual the main features of this technique have been outlined. The variety of effects that will be obtained by using this recipe: *graphite ink, orange*

oil and cobalt drier, is very much in the hands of each etcher and their experience of the method.

After becoming familiar with the ease and flexibility of etching with electrolysis, I have given up using toxic sprays, melted rosin and asphaltum, paint and aerosols containing varnish or diluted polymers, which require the use of special booths and dust masks to avoid inhaling the small particles released by the aerosols or airbrushes.

The new, alternative methods which apply acrylic resists with an airbrush give good results on copper plates etched with *Edinburgh Etch* solution –see *Glossary* on page 184 and *Websites* on page 201. However, I do not think that the fine layer of particles of acrylic ground can withstand the action of the electrolytic tank very well and I have found through my experimentation with these grounds that a double coat must be applied in order to resist the bite.

In short, despite the differences between *aquatint* and *electrotint* –the methods and the different tonal effects– I recommend that you try this technique, get to know it, discover what it can offer, practice it and, little by little, learn to enjoy *anodic etching*.

Lift-ground process

A wonderful way of drawing lines and brushstrokes directly onto the plate is the traditional and versatile lift-ground method, which is based on the incompatibility of the resist with another, different substance. This method is based on drawing on the plate directly with a substance that will later lift off the varnish. Lift-grounds are classified according to whether they are water or oil-based.

Water-based lift-grounds

For a traditional etching liquid ground (one made with wax and asphaltum) use a water-based lift-ground. Any of the usual black Indian ink and sugar recipes can be used, with varying amounts of water, soap, etc. Three of these water-based recipes are provided below:

- Recipe 1. Add sugar to an amount of water sufficient for the drawing until no more sugar will dissolve. Then add a small amount of coloured tempera.

- Recipe 2. Add sugar to an amount of Indian ink sufficient for the drawing until no more sugar will dissolve. A little water may also be added to this recipe.

- Recipe 3. Mix acacia syrup with a small amount of tempera and a few drops of water.

The use of the water-based lift-ground involves the following steps:

- Prepare the plate with the contact-strips and degrease it
- Draw with any of the above recipes you have prepared on the plate with paintbrushes, wooden sticks, or mark it with different tools
- Let the ink dry thoroughly
- Cover the entire plate with liquid ground and leave it to dry
- Submerge the plate in warm water until the ink dissolves and the ground covering it peels off –the plate can be rubbed gently with cotton wool or a cotton bud to help the removal of the ink
- Degrease the plate again with vinegar and salt.

Finally, introduce the plate into the electrolytic bath following the electrotint processes previously described, you will obtain the diverse effects of micro dots offered by this technique.

Test strips of lift-ground with acacia syrup and tempera and electrotint with open bite at intervals of 15 minutes. On the left, copper plate, 200 g/l - 0.5 V. On the right, zinc plate, 160 g/l - 0.5 V.

Oil-based lift-grounds

When using the non-toxic acrylic floor wax hard ground or *Lascaux*'s hard resist, it is necessary to use an oil based product to draw the image: an oil-based lift-ground. Lithographic pencils, wax bars, lipstick or any other solid oil material may be used.

The use of the oil-based lift-ground involves the following steps:

- Prepare the plate with the contract-strips and degrease it
- Draw with any of these oil-based products
- Cover the entire plate with the acrylic floor wax hard ground as explained on page 51 or apply *Lascaux*'s hard resist with a paintbrush
- Let the acrylic varnish dry at room temperature
- Heat the lift-ground with a hot air dryer and rub it gently with a cotton cloth to help the varnish peels off. Similarly, when the *Lascaux* varnish is dry, the wax we have drawn with can be lifted off but without the need to heat the plate –simply scrape the drawing with your nail
- Degrease the plate again with vinegar and salt; and then follow the electrolytic processes described to obtain electrotint.

Remember, if the lift-ground is water-soluble, submerge the plate in warm water and rub it gently with some cotton wool until the ground over the ink becomes detached. If the lift-ground is oil-based, heat the plate with a dryer and rub with a piece of cotton wool until all traces of it have been lifted from the drawing.

When oil-based intaglio ink is used as a ground, the lift-ground process described by Cedric Green on *Green Print* can be used. For the lift-ground a solution of sugar water with a few drops of Indian ink to give it colour and a drop of liquid soap are used.

Degrease the plate and draw with this mixture using brushstrokes that are not too narrow; dry it a little with hot air until it is sticky; then press a paper towel over the mixture, taking care that it does not wrinkle, until the paper is soaked and you can see the mixture through the paper. If the paper is very thin, remove it and leave the sugar-water mixture to dry completely. Spread the ground (intaglio ink) with a soft roller, pressing on the sugar mixture so that it penetrates the pores left by the paper.

Let the ground dry thoroughly and then put the plate in a tank of water until the sugar has dissolved.

This method, which can be mastered with practice, gives interesting textured lines. However, it is necessary to achieve the correct balance between the dryness of the lift-ground and the amount of sugar lift-ground removed by the paper. Problems can be caused by the paper absorbing too little moisture before it is lifted, as may happen for example, when the mixture is too dry or the paper is lifted too soon.

Finally, degrease the plate again with salt and vinegar and continue with the electrotint processes to generate micro dots.

Soft-ground process

This traditional technique can be applied to electro-etching using various types of soft ground. The same, familiar methods are used to create the drawing on the plate. The crayon effect can be achieved by drawing with different graphite pencils on soft paper that has some texture or grain, on a plate that has already been spread with a fine and even layer of ground.

In addition, different textured materials can be pressed into the ground or it can be worked directly by rubbing it with any available material.

I have used three types of soft ground for zinc, copper and iron plates. A traditional commercial soft-ground which did not give very good results with electro-etching because it is not sufficiently opaque to the electrolytic action. The so-called *Soft ground 150*, made with a recipe that the Professor Jesús Pastor provided years ago in the

etching workshop of Cabildo de Gran Canaria. Since then I have continued to use his recipe as much for its opaqueness as for the fact that it allows stop-out to be used on lines to obtain even more value from different bites and is very effective for electro-etching. In addition it allows scratches or unwanted lines to be touched up with stop-out before biting the plate. The third ground is the versatile graphite ink which I like best for electro-etching.

The *soft ground 150* is made using the recipe of Jesús Pastor:

150 g virgin wax
75 g rosin dust
500 g black litographic ink
150 g lard

Inhaling the gases given off during the preparation of the ground should be avoided, use a face mask and a ventilated work space.

The ground is prepared using a double-boiler in the following way: 1. Melt the virgin wax / 2. Add the rosin in dust form and stir / 3. Mix in the litho-graphic ink until it forms a smooth paste / 4. Add the lard / 5. Put the mixture into a container / 6. At the end of the process you can add between 200 to 250 cm^3 oil of turpentine to soften the ground.

Application of the soft ground

On a plate that has already been prepared with the contact-strip and degreased, apply the ground with a plastic or wooden palette knife. Heat the plate a little on the hot plate and spread the ground with a roller, going over it a number of times until the surface is covered with an opaque and even layer. The plate can be heated a little more, if necessary, to ensure that the ground is spread completely evenly. Leave it to cool and proceed to work on it with any of the techniques described.

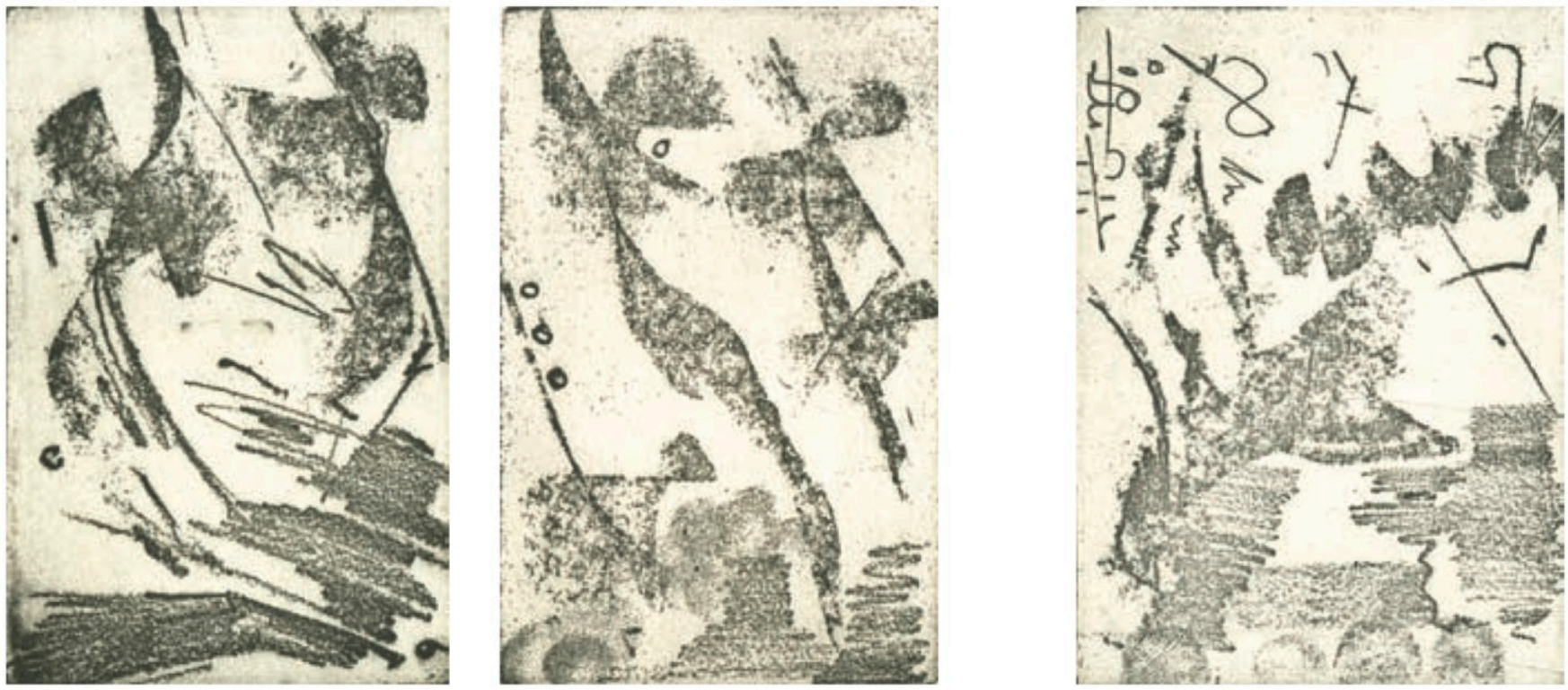
Heat cannot be used to dry the ground and because of this, the process is relatively slow. Place the plate in a dry, well-ventilated spot, leave it for several hours. It can then be placed in the electrolytic bath, even though the ink may not be totally dry. Given that the *soft ground 150* has the quality of being very opaque to the bite, it can be etched several times using a stop-out ground as required.

The main drawback of this ground is that it gives off toxic fumes so a mask must be used for protection. We will look at its non-toxic alternative later.

Electrolytes, voltages and bite times

Soft ground on copper plates

Good results can be obtained with any of these concentrations: 160 g, 200 g or 250 g/litre of water. The voltage can be a little higher, ranging between 0.5 and 1 V for longer periods of time. Even if there is some bite after 60 minutes, I have achieved better results with times up to 120 minutes.



Test strips with soft ground 150 crayon technique. Left and centre, copper plates, 160 g/l - 0.5 V - 60 mins, 200 g/l - 0.5 V - 60 mins. On the right, zinc plate, 200 g/l - 0.5 V - 90 mins.

Soft ground on zinc plates

The solutions that have produced the best results are rather concentrated, between 225 g and 300 g/litre of water. The voltage must also be somewhat higher than for lines and electrotint. Use 1 V for long periods of time, between 60 and 120 minutes. When carrying out long bites to obtain intense tones, it is best to interrupt the electrolytic action on the plate from time to time, rinse the plate and bite it again for shorter intervals, up to the total time required. This will produce better results than one uninterrupted bite of 120 minutes.

Soft ground with graphite ink

Prepare the ink as previously explained for hard ground. Spread the ink with a roller as if it were a hard ground and, simply, work on the layer of ink before it has dried, as if it were a soft ground. You can use the crayon technique, or leave prints of any texture by applying pressure to the plate with different materials.

A characteristic of soft ground with graphite ink is that it dries slowly, which is one advantage of working with it. However, it is necessary as ever to dry the graphite ink before putting the plate into the electrolytic bath to avoid foul biting –etching of deep holes or unwanted details. The drying process can be accelerated by using a hot plate before beginning to electro-etch.

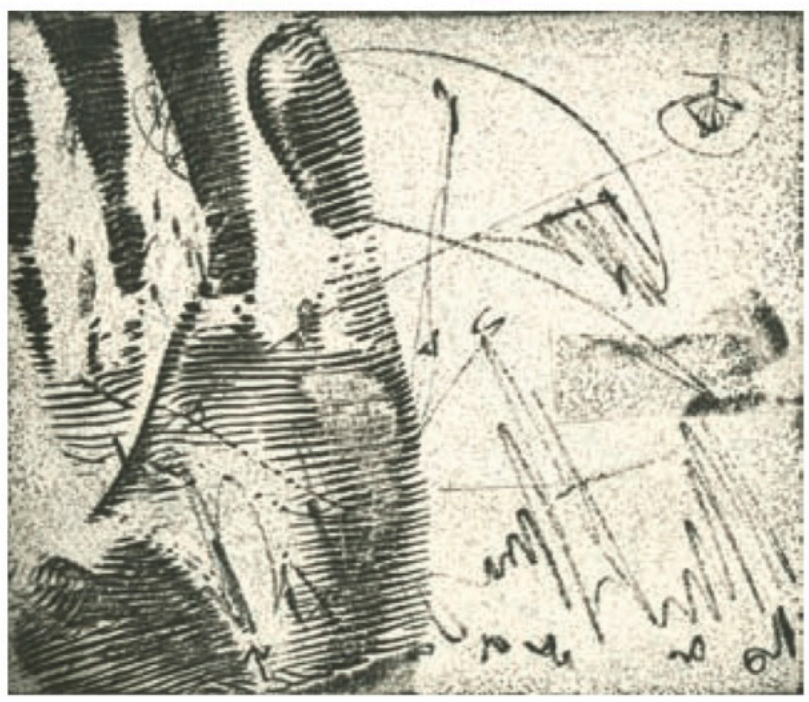
Always remember to add a few drops of cobalt drier to the graphite ink, this will accelerate the ink's drying time, but will not prevent it being worked like a soft ground.

A single impression made by pressing on this ground with some materials may give differing tones so we can etch for a single period of time without needing to do multiple bites.

Soft ground with graphite ink on copper plates

The solution can be 200 g/litre of water, a voltage of 0.5 V for 60 minutes will be sufficient.

Electrolytes, voltages and bite times



Etching with soft ground of graphite ink. On the left, crayon technique on copper plate, 200g/l - 0.5 V - 60 mins. On the right, zinc plate, 300 g/l - 1 V - 90 mins.

Soft ground with graphite ink on zinc plates

The solutions which have given the best results are rather concentrated, between 250 g and 300 g/litre of water. Use a voltage of 1 V for 60 minutes.

Relief etching deep bite (Embossing)

The electrolytic process allows deep bites to be made. If large areas of metal are to be exposed in the electrolytic bath, a higher voltage from the power supply and longer etching times are needed.

To protect the plate use any of the grounds already mentioned, applying several layers if necessary. It is best for the ground to be thoroughly dry and care must be taken to ensure that unwanted pores do not open during the long bites. Remove the plate from the electrolytic unit from time to time, rinse it, dry it and check that the ground is not deteriorating. If it is, cover the areas that have peeled off, or are about to do so, with stop-out. Self-adhesive plastic such as *Fablon*™, or electrical insulating tape are excellent stop-outs.

This process has several advantages and one disadvantage. Among one of the most important advantages is the following: in contrast to biting with acids, the edges of ground do not peel off with electrolytic corrosion, but are usually clean in spite of prolonged exposure to the bite, so that the action of the bite by electrolysis is and remains perpendicular to the surface of the plate.

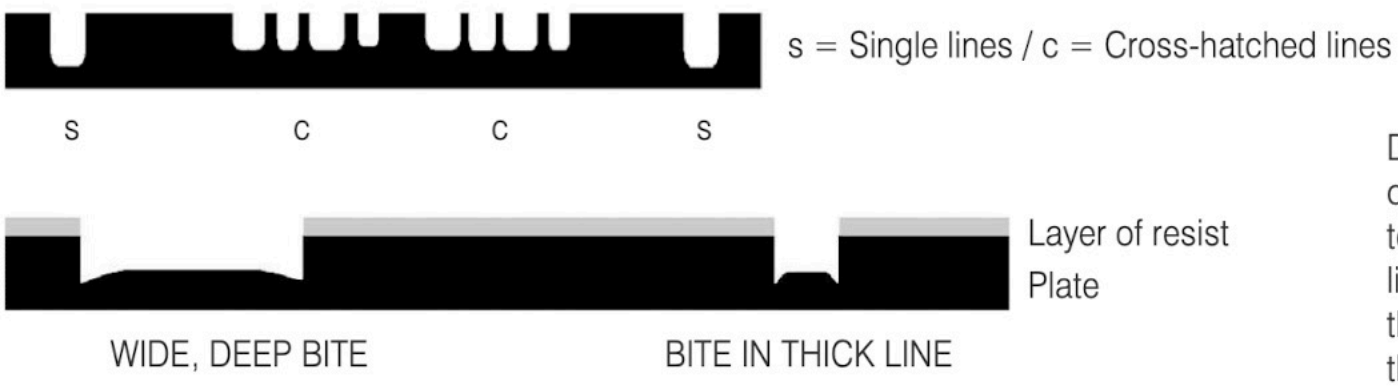
Difference between corrosion with acids and the electrolytic bite.

Another advantage is that the surface at the base of the bitten area produces micro dots which gives a different tone compared to the bare patches formed by acids. Moreover, it is unnecessary to pay constant attention to the process in order to deal with bubbles or residues in the bite since they do not occur with the low voltages used. The solutions will not become exhausted and, of course, they will not give off toxic gases.

The drawback is the *edge effect*, which I explained in the paragraph *Characteristics of the electro-etch "bite".* This is the tendency to bite

more quickly, and as such, more deeply at the edges of the resist when large, flat surfaces are exposed to electrolysis.

This same effect occurs at the edges of broad lines, that is, the electrolytic action acts with greater intensity at the edges of the resist on large areas of open bite. However, all things considered, it is not a major disadvantage.



Difference in the depth of the bite according to the placement of the line and, below, effect of the bite at the edge of the resist.

Use a cathode grid or a strip of metal narrower than the etching plate in order to try to minimise this effect or try to use it for graphic effects. No method is perfect!

The electrolytes that can be used are the same as those described for the previous processes, for both copper and zinc plates: concentrations of 200 g/litre of water for copper and between 250 g/litre and 300 g/litre of water for zinc. The voltage must also stay within a low range, that is, no more than 1 V.

Remember that if you want to experiment with this process using higher voltages, for safety reasons, never raise the voltage above 6 V.

Taking into account that these bites are protracted, and that you will possibly be absent from the etching workshop for hours, it is best to keep a low voltage. With this process Marion and Omi Behr have managed to etch through the plate thickness after bites of 25 or 30

hours. However, in order to get a deep bite on zinc plates I recommend that you use the process called *Passive electrolytic etching*, which will be explained later.

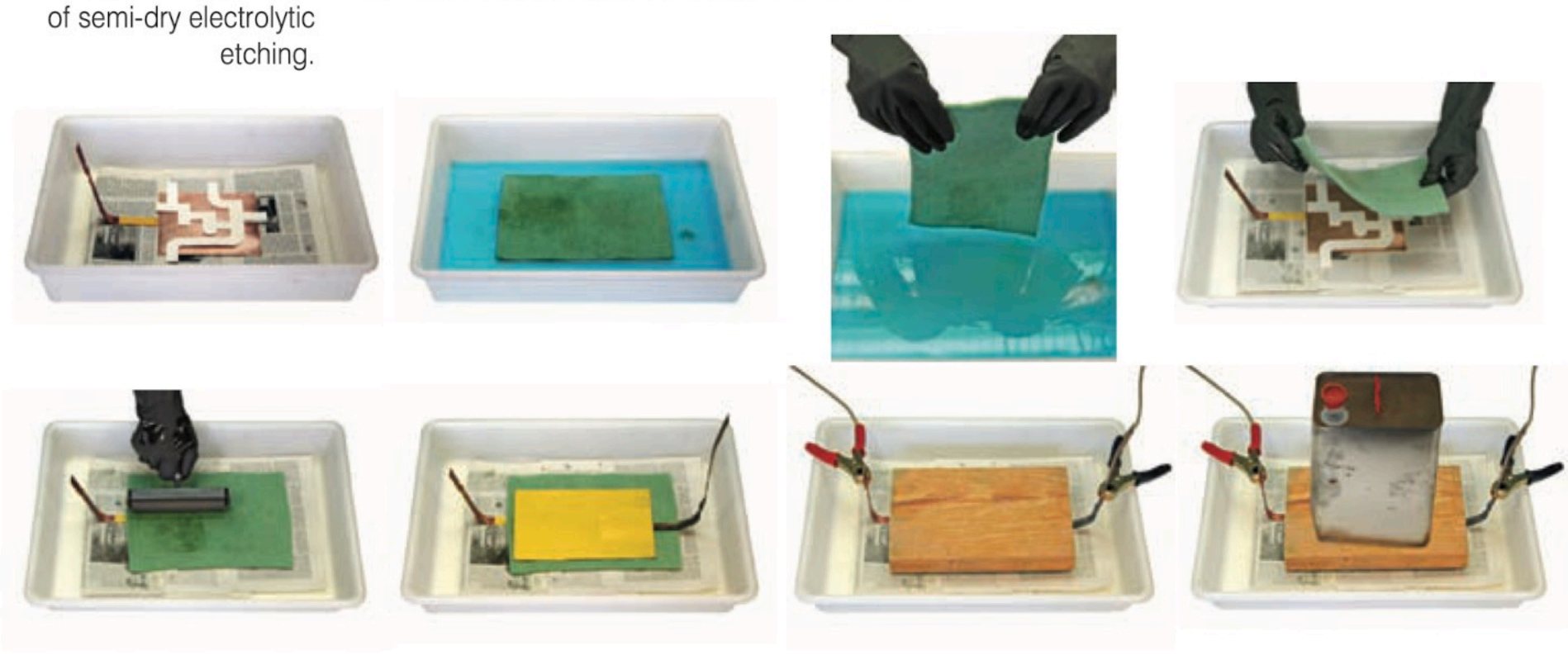
Semi-dry electro-etching process

This interesting method of electrolytic etching was invented by Cedric Green who called it the *Galv-on semi-dry method*. As the name suggests the process uses a variety of materials flattened between the plates to form a sandwich, with felt soaked in electrolyte in the centre, without having to submerge the plates in the electrolytic tank.

It is ideal for producing a large amount of texture of micro dots on open areas of metal and enables large plates to be worked on without the need for a large vertical electrolytic tank.

Prepare the plate with a contact-strip and degrease it. Either protect the whole plate with any resist and draw on lines or apply the resist only on those areas that you do not want to etch leaving bare metal for producing micro dots or textures. The varnish must be dry for the application of this method.

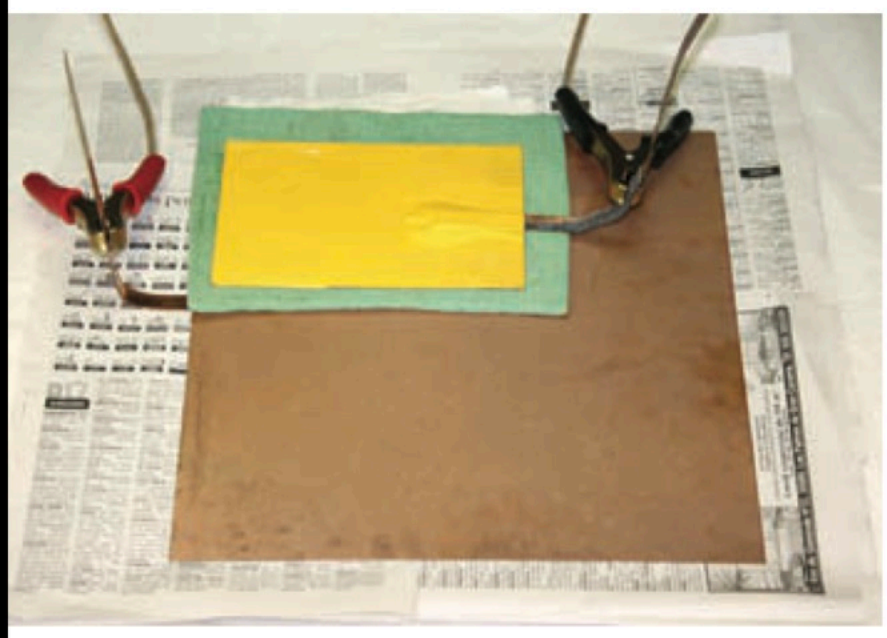
Steps in the process of semi-dry electrolytic etching.



Lay the plate to be etched in the bottom of a plastic tray, etching-face up, with some sheets of newspaper or blotting paper underneath it. If it is a large plate, instead of a tank you can use a plastic sheet or covering so that the electrolysis does not damage the table.

A thick piece of felt soaked in the correct electrolyte for the metal you are going to bite is required. Beforehand this felt should be washed

with soap to get rid of the natural oils in the wool. Place the felt on the surface of the etching plate and, with a hard roller, press to get rid of any air bubbles that can impede the bite. Put a plate of the same metal (degreased and with its contact-strips facing upwards) on top of the felt to make a sandwich –etching plate/felt/ cathode plate. The surface of the metal must be completely uncovered on the side of the felt and facing the plate or the area that we are going to etch. This last plate will act as a cathode. Put a thick, flat block of wood on the cathode plate and, on top of that, a heavy weight (10 -12 kg).



Process of semi-dry electrolytic etching being applied to a specific area of a large plate.

Connect the contact-strips to the power supply. Remember, the etching plate is the anode and it will be connected to the positive pole. The cathode plate will be connected to the negative pole. The current will pass through the electrolyte in the felt and will etch the bare areas of metal. Longer etch times are required as compared to etching in a tank with liquid electrolyte.

For a line drawing, after the hard ground has been applied and worked with needles on the plate, place several sheets of very fine blotting paper or paper napkins –soaked in electrolyte using a paint-brush– between the plate and felt. Roll them thoroughly with the roller before placing on the electrolyte-soaked felt. Then the roller must be used again on the felt blanket in order to avoid air bubbles forming. Finally, complete the sandwich with the cathode plate and place the weight on top.

It is advisable to do a test plate with different types of lines: single lines and cross-hatching for varying time intervals, using different electrolytic concentrations until you achieve the effects you want. I prefer to bite etchings that contain lines with liquid electrolyte in a vertical tank. I mostly use this process for tonal effects.

Tonal effects on open surfaces

There is a large range of combinations that can be used with this method to create tonal areas on open surfaces of the plate: a variety of effects can be achieved, depending on the porosity and the structure of the materials inserted between the felt and the etching plate.

For example, it is possible to use the texture of the same felt, or another finer felt, or insert cuttings, paper drawings or other dry materials like thread, leaves, or fabric that will gradually allow the electrolyte from the felt to filter through, etching to different depths. Another option is to soak these materials in electrolyte, taking into account that they can have an unequal resistance to the current and, because of this, can also create interesting effects. In addition, grains of table salt or sulphate can be spread over the plate to get good areas of intense colour. A product with the brand name *Vallejo*, which is a mixture of white pumice and titanium white, can be applied to the metal to produce tonal degradation.

You can also practice drawing on paper with water-resistant ground. Once the ground is dry, soak the paper in electrolyte and place it on the etching plate, which has previously been prepared and degreased. Then set up the sandwich of blotting paper and felt soaked in the electrolyte, connect the contact-strips to the power supply at

Etchings with the semi-dry electrolytic method. On the left, zinc plate, 250 g - 1.2 V - 60 mins. On the right, copper plate, 250 g/l - 1.2 V - 90 mins.

their respective poles and apply the current for a long period of time. The result will be a negative image of the drawing on a background of tones and textures created by the paper and felt soaked in electrolyte. It is well worth experimenting with all the different ways in which this process can be applied.

Washing the felt

When the etching has been completed, the felt should be rinsed in water, washed with soap, rinsed again, dried and stored in a condition suitable for future use with this semi-dry method. If it has been etched with copper sulphate, rinse the felt in the rinsing tank with iron wool, before washing it with water and soap.

Electrolytes, voltages and bite times

Semi-dry electro-etching on copper

The solution can be 250 g of copper sulphate / litre of water and a voltage of 1.5 V used for 60 minutes or more.

Semi-dry electro-etching on zinc

The solution can be 300 g of zinc sulphate / litre of water and a voltage of 1 V used for 60 minutes or more.

In passing I would like to mention an interesting result obtained when I accidentally put a felt soaked in copper sulphate electrolyte between two zinc plates and applied a low voltage. A deeper etch with brighter tonal effects as compared to a zinc electrolyte was obtained –see picture below. The concentration of copper sulphate was 250 g/litre of water and the voltage was 1 V, with printable results from 30 minutes. If you experiment with this process yourself, always follow the recommended safety and disposal precautions applicable to copper sulphate.

Etching with the semi-dry electrolytic method on zinc plate, 250 g of copper sulphate/l - 1 V - 60 mins.

Electro-etching without electricity

An interesting approach to etching zinc plates without the need for an external power supply is based on the early types of battery invented at the beginning of the 19th century. These consisted of one plate of zinc and another of copper submerged in a solution of copper sulphate.

In 1840, T. Spencer and J. Wilson discussed the possibility that two different metals submerged in the correct solution, facing each other in parallel and connected externally outside the electrolyte, would generate a flow of electric current sufficient to displace the copper ions. The system does not need a power supply since it acts like a voltaic battery, so forming a "self-etching" electro-chemical unit.

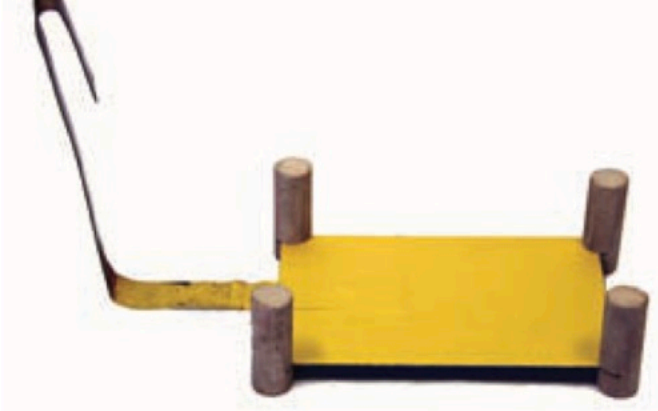
Passive electrolytic etching of a zinc plate

This electrolytic application updated by Cedric Green is a very simple process. It requires a copper plate which acts as the cathode and a zinc plate which acts as the anode and is the plate which is to be etched. The electrolyte used is copper sulphate and two copper strips are required to make the electrical connections. Copper must be used because connecting a zinc plate with a zinc strip which will be partially submerged in the electrolyte would result in its corrosion even though it is protected by self-adhesive plastic tape.

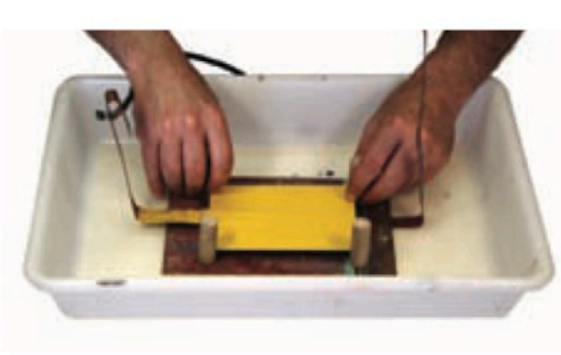
I generally use a large, flat, plastic tray for passive etching of large plates in preference to a vertical tank because the handling of the plates is easier. A vertical tank can be used for small plates.

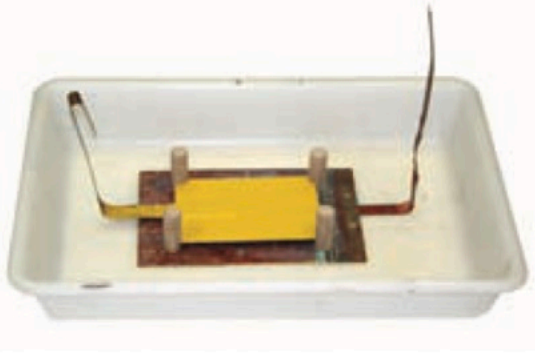
The electrolyte is held in a flat plastic tray large enough to fit the plates in comfortably and a crocodile clip is used to connect the contact-strips which allows the electric current to flow. I prefer to use a connection made up from an insulated wire conductor 20 or 30 cm long, to which are soldered two small crocodile clips –one on each end, this allows the contact-strips to be connected easily.

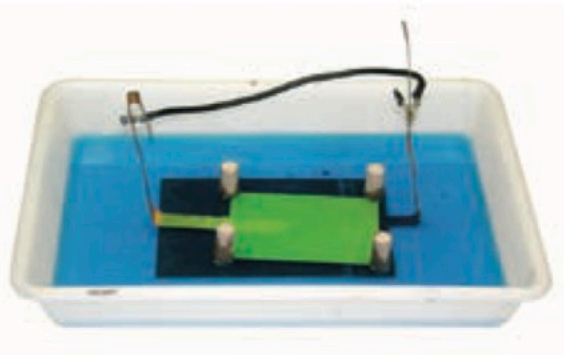
Finally, as the plates need to be submerged in the electrolytic bath facing each other, in parallel, 1 cm apart, I have prepared spacers using wooden plugs approximately 4 cm high and 2 cm in diameter, with a groove at a height of 1 cm, which I use to support the zinc plate. There may be other ways to keep the plates at the correct separation in the electrolyte and electrically connected –see next page.



Steps in the passive electrolytic etching process.







Line drawings may be etched, or alternatively, areas of bare metal may be left on which micro dots for electrotint can be generated. The zinc plate is prepared by attaching the connecting strip and then degreasing the plate. Then the ground is applied using any of the resists previously mentioned; this may be drawn on while still wet if required but must be completely dry before undertaking the electrolytic process. A copper plate is similarly prepared with a contact-strip and degreased, then placed in the bottom of the tray with the open face upwards and the contact-strip sticking out of the tray. The zinc plate, with the spacers attached to give the 1 cm gap, is placed in the tray with the face to be etched parallel and facing the copper plate. Outside the tank, the two contact-strips are connected using the connecting wire with the crocodile clips. Finally the electrolyte solution is added to the tray.

Vertical tanks

As an alternative, for small plates, a tank may be improvised from a plastic container to hold the plates vertically. Slots are cut in the upper part for positioning the electrodes. The electrodes are made from a single copper bar 1 cm thick, 1.5 cm wide and a little more than twice the length of the tank in length. The bar is bent in half in a “U” shape with the two arms separated by about 1 cm –see next page. The copper and zinc plates are hung opposite one another on the two arms using their contact-strips. These are fastened to the copper bar using crocodile clips to ensure good electrical contact.

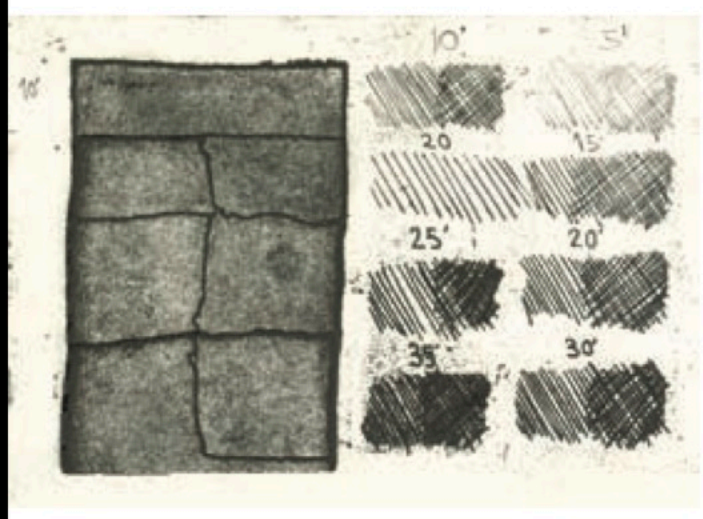
Vertical tank made with a plastic container, electrode with the contact bar, on the left; vertical tank with electrolyte in the centre, the electrode with the contact bar and plates hung; on the right, manufactured narrow vertical tank, copper electrode on the upper edge and plates hung.

For small plates I have designed a vertical tank, made in a plastics workshop. The dimensions are: 40 cm long, 30 cm high and 2 cm wide internally. A copper connecting strip 1 mm thick and 1.5 cm wide has been fixed around the outside perimeter of the open top without the two ends actually joining. The copper and zinc plate, suitably degreased and with their contact-strips attached, are hung from opposite sides of the tank with their contact-strips making good electrical contact with the external connecting strip (crocodile clips may be used to ensure good electrical contact).

Electrolytes and bite times

A copper sulphate solution is used as the electrolyte. For line work a concentration of 160 g/litre of water is used while for fast etching of deep, open bites a larger concentration of 250 g/litre of water is advisable. It is a good idea to etch a test plate with different lines and open bites at regular intervals of time. However, bear in mind that as the solution becomes exhausted, the bite times need to be calculated intuitively, as for etching with acids.

Zinc plates with passive electrolysis. Left, test strip with lines and



electrotint of open bite, 250 g/l and eight intervals of 5 mins. Right, etching with open bite, self-adhesive plastic and stop-out resists, 250 g/l and four intervals of 15, 30, 15 and 30 mins.

Print by Eliseo Méndez, carried out on zinc plate using passive electrolysis. Soft grounds process, using stop-out varnish before drying it, 250 g/l, intervals of 10 mins.

Characteristics of passive electro-etching

This passive etching technique retains the advantages seen with electro-etching using a power supply (*active electrolytic etching*): the etching action is very effective, a deep vertical bite may be obtained, and the resist at the edge of the bite, if applied correctly, does not peel off but remains strongly attached to the metal surface. Furthermore, when using a new copper sulphate solution this method etches faster than all other techniques that I know, particularly when an "add on" piece of equipment, a *saline reservoir*, is used –see page 90. As with the *saline sulphate etch*, some hydrogen may be produced as a side reaction to the etching.

I have checked that in this passive process the perpendicular bite on the plate is of the same depth on the open metal surfaces as on the edges of the resist. This is the opposite to what occurs with the action of active electrolytic etching using a power supply, for this same type of extended, deep bite.

Effect of the bite on the edge of the resist.

Bearing in mind that copper is quite a lot more expensive that zinc, I rarely work with deep reliefs on copper plates. All of my embossing work has been done on zinc using this complementary process.

If the zinc plate is placed at the bottom of the tank the residues that are generated on the bare metal surface, if they are not removed, can be used to create tonal effects*, even if the tone is beyond the control of the etcher. However this position is no good for etching lines because the residue will halt the etching process.

* Another type of electrotint.

To generate tonal effects some "tricks" can be used to make a "stopping-out pattern". This is achieved by picking up some hard or soft ground on the surface of a piece of fabric or wrinkled paper and then applying them to the surface of the plate to create an irregular pattern of resist marks. This is allowed to dry and then the plate is bitten for a short time. This process is repeated several times. See *Masking techniques* on page 64.

Disadvantages of passive electro-etching

The process has some drawbacks which must be borne in mind:

- Unlike *active electro-etching*, an open bite does not generate characteristic "natural" micro dots: it is necessary to employ the electrotint processes explained in earlier sections.
- In the tray, the zinc plate must be placed face down as the process generates metal residue which sinks under its own weight*.
- Most significantly, the electrolytic solution becomes exhausted and loses its ability to bite, something that does not happen with the *active electrolytic process*.
- The evolution of hydrogen, requires working in a well ventilated environment –outdoors in the open air or the use of suitable air extraction, as a fume extractor hood.

* In the vertical tank the residue that does not adhere to the copper plate sinks to the bottom.

Treatment of the used electrolyte

Once the solution has been used for a passive etch, the metallic residue should be filtered from the electrolyte using paper or fabric as a membrane. Then the electrolyte solution can be stored in plastic containers to be reused until it becomes exhausted. The copper residue should be dried and eventually disposed of at an appropriate local authority waste collection depot.

When the solution is nearly exhausted (at which point it will etch slowly) the solution changes from a deep blue colour to a pale blue. What has happened is that the copper ions of the solution, positively charged and attracted towards the copper cathode, are gradually replaced by zinc. As a result, the original copper sulphate solution is gradually transformed to a solution of zinc sulphate together with a metallic copper residue.

While this zinc sulphate solution ceases to be of any use for the passive etching, it can be used for active electro-etching of zinc using a power supply. However, before it is suitable for this application, the copper sulphate solution must be completely exhausted. This is achieved by adding any scrap pieces of zinc to the solution until it becomes completely transparent and colourless: the copper is completely precipitated out of the solution. After filtering out this metallic residue, the solution can then be used for electro-etching of zinc.

The passive electro-etching is a technique that allows us to recycle the spent copper sulphate solution effectively providing a cheap way of obtaining a zinc sulphate solution which is pure enough not to produce residues when electro-etching.

Passive electro-etching with a saline reservoir

As time goes by, new techniques have been incorporated and processes improved. The saline reservoir is a surprising "add-on" for accelerating the biting process in passive electrolytic etching. This "add-on" was suggested by the chemist Paco González to Paqui Pagan –an etcher who attended one of my courses and subsequently sent me a drawing of the equipment. It consists of connecting the main tank that contains the copper sulphate solution to another tank containing a saturated common salt solution. The tanks are linked by a glass U-shaped tube with dry cotton wool at each end. The tanks are

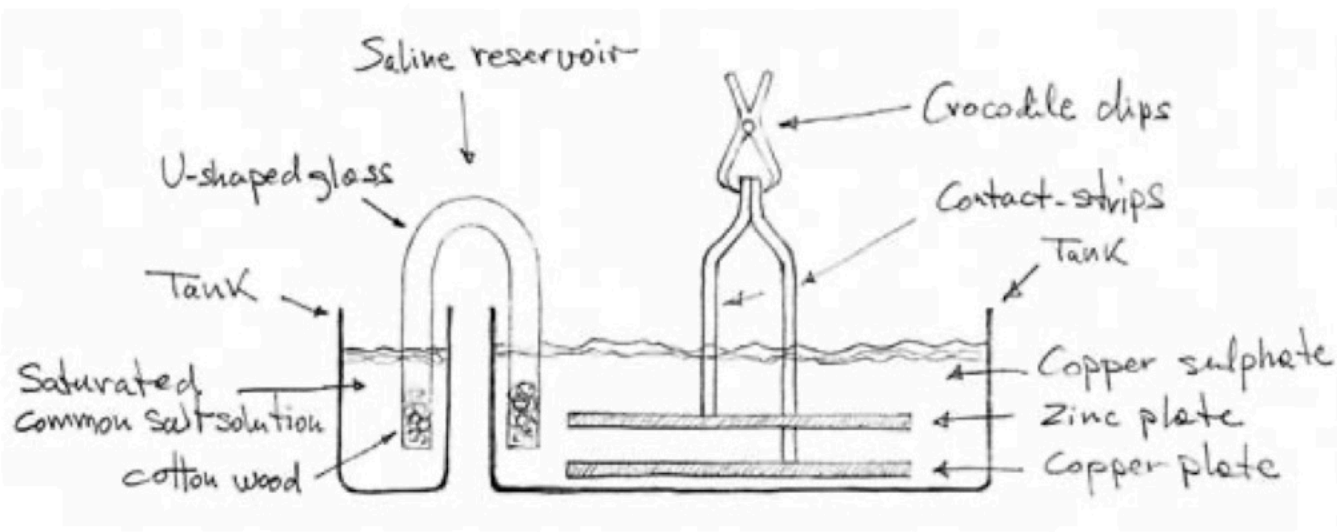


Illustration of saline reservoir, on the left; below, U-shaped glass tube with cotton wool and saline reservoir formed by the tank for passive electrolytic etching and the tank of salt and water.

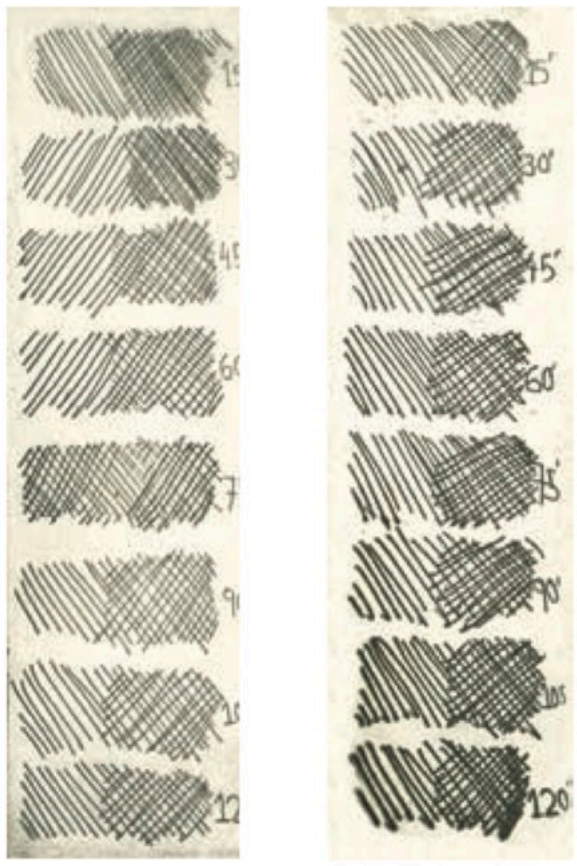
placed close together and the saline reservoir is inserted, as seen in the picture. The saline reservoir can be left for as long as the different steps in the etching process last.

The exact mechanism which gives rise to the faster etching is not completely understood. However, it is believed that the cotton wool plugs which become saturated with their respective solutions are joined by a thin film of the saline solution which consequently feeds ions from the saline solution into the main tank. These ions interact with the zinc to assist the etching process.

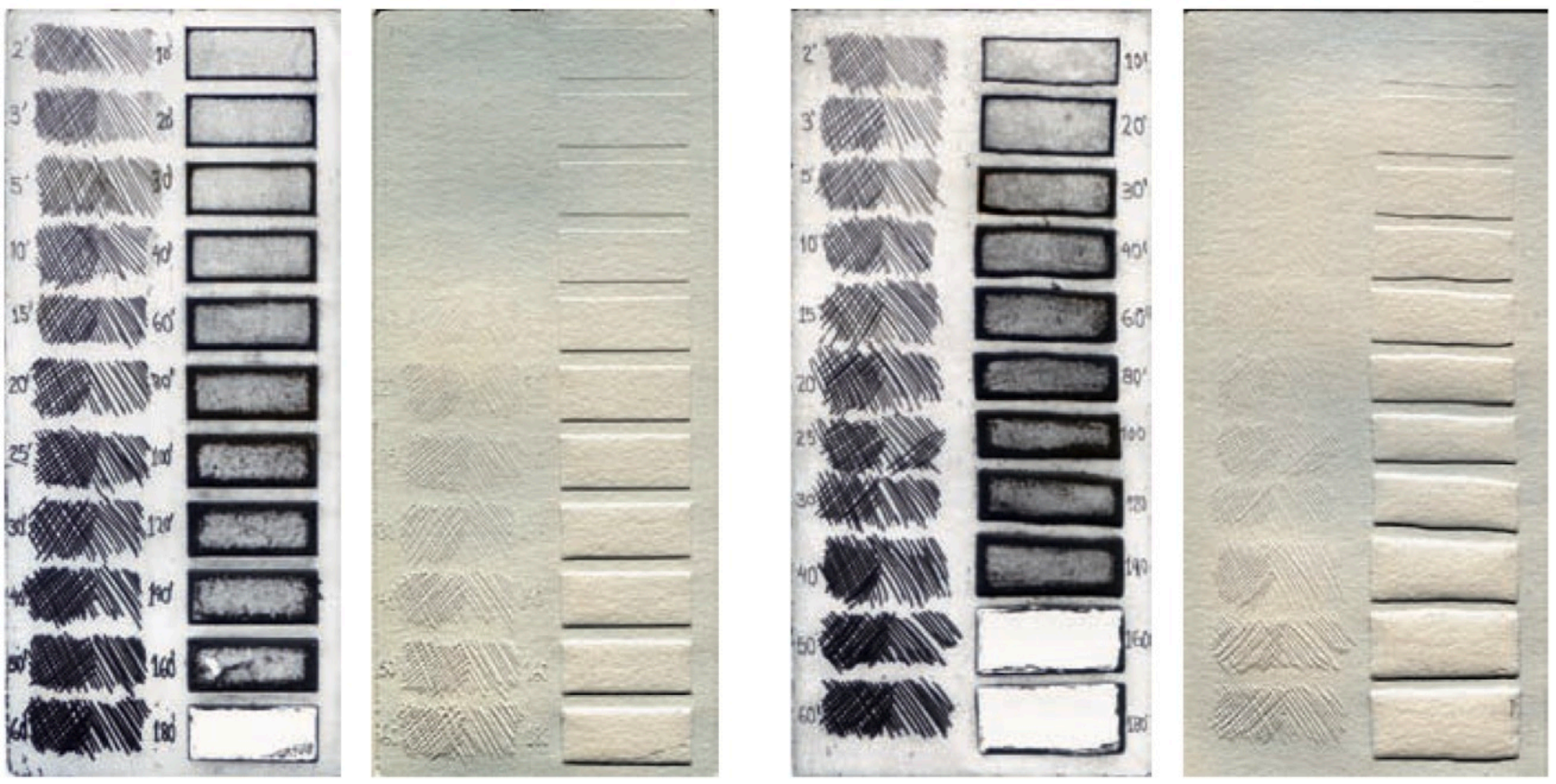
For zinc plates, using *active electro-etching* with a power supply, a zinc sulphate electrolyte of 300 g/l and 0.5 V, a typical etching time for lines is 15 minutes. For *passive electro-etching*, the time is reduced to only 2 minutes when using a copper sulphate electrolyte of 250 g/l.

A deep bite made in 100 minutes *with passive electro-etching* can be obtained in 80 minutes *with the addition of the saline reservoir*. A bite of 1 mm depth can be achieved in 180 minutes *without a saline reservoir* while *with the saline reservoir* it is obtained in 160 minutes –see *Comparative data chart* on page 179.

The etching process *using the saline reservoir* keeps the integrity of the line edges for longer. *Without saline reservoir* the edges progressively widen after 10 or 15 minutes. However, the edge of the varnish does not break down as violently as a deep bite with acid. See test strips in the picture.



Comparative test strips with the active and passive electro-etching process on zinc plates. Above, on the left, *active electro-etching*, a zinc sulphate electrolyte of 300 g/l - 0.5 V. Etched lines bitten at 15 minutes intervals. On the right, same process but 300 g/l - 1 V. Below, *passive electro-etching*, on the left *without saline reservoir* and on the right *with saline reservoir*. For both plates: A copper sulphate electrolyte of 250 g/l. Etched lines intervals from 2 to 60 mins. Open bite etched intervals from 10 to 180 mins. Intaglio printed and embossed print.



Semi-dry passive electro-etching process

This technique is the result of combining two processes: *passive electro-etching* and *semi-dry electro-etching*, both described previously.

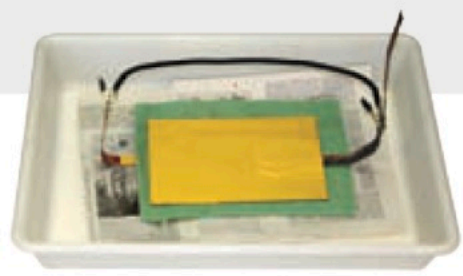
In order to etch a zinc plate, proceed as in the previous paragraph: prepare the zinc plate with the contact-strip, degrease it, protect it with a suitable resist for the intended work and allow it to dry. Next, place the plate in the bottom of the plastic tank, with the face that will be etched facing upwards, on top of it place a thick piece of felt that has been degreased (see earlier section) and then soaked in the electrolyte. Depending on the work to be carried out blotting paper soaked with the electrolyte may also be used.

Having degreased the copper plate (the cathode) and attached the contact-strip, it is placed on top of the felt. Next, a weight is placed on top of the copper plate, the plates are connected electrically using the contact-strips, and the process begins to work. The small distance between the plates will generate a strong current which will eliminate all (or nearly all) the precipitate. Use similar concentrations as with the passive method.

My advice is to make a test plate for different time intervals with simple lines and cross-hatching drawn on the plate; areas of open bite left to generate micro dots, or areas where the textures of materials sandwiched between the felt and the bare areas of metal have been transferred. This process is also suitable for working on isolated areas of large plates: by forming a sandwich with the etching plate, a piece of electrolyte-soaked felt the size of the area to be etched, the cathode plate, and then connecting the plates via the contact-strips.

Below, image of a plate prepared for etching with the semi-dry passive electrolytic method before placing the weight on.

Remember that the semi-dry passive process is only applicable for etching zinc plates and bite times are long.



Galvanising, Electroplating or Galvanoplasty

In order to extend the unique qualities offered by the electrolytic process, we must remember what takes place at the cathode when we connect the current to the electrolytic unit.

Principles of galvanising

We know that the electric current flows from one plate to the other through the solution and that the positive and negative ions of the electrolyte separate and are attracted to the plate of the opposite polarity. The negative sulphate ions are attracted to the bare areas of the anode, corroding (etching) it! This is the property that we have taken advantage of up to now in the previous etching processes. But, what happens at the cathode plate? The positive metal ions "stick" to the bare metal of this plate: it is galvanised due to the effect of electroplating. If you look at the plate or grid that has been used as a cathode for the previous processes, you will see that there is a large quantity of metal particles attached to it. The techniques that I am now going to describe are based on taking advantage of this particular electrolytic quality.

For this process, no new equipment or special tools are needed in the workshop: the poles of the electrolytic unit just need to be reversed. That is to say, the plate that we are going to galvanise, must be at the negative pole, receiving the small particles of metal, face to face and in parallel with the other plate, situated at the anode of the electrolytic tank, which will "provide" these metal particles.

If with your usual electro-etching unit you have a copper plate as the cathode at the negative pole, it is not necessary to remove the plates from the electrolytic tank but only to change the terminals of the power supply, applying the negative pole to the plate you want to galvanise. However, if a stainless steel grid is used as the cathode, it will be necessary to remove it from the tank and put the plate you want to galvanise in its place, and do not change the terminals.

To obtain a coating of metal on the plate at the cathode, a piece of the same metal is placed at the anode (positive pole). It is important to appreciate that this *donor plate* must be degreased and not coated with a resist since its purpose is only to act as a source of metal: it

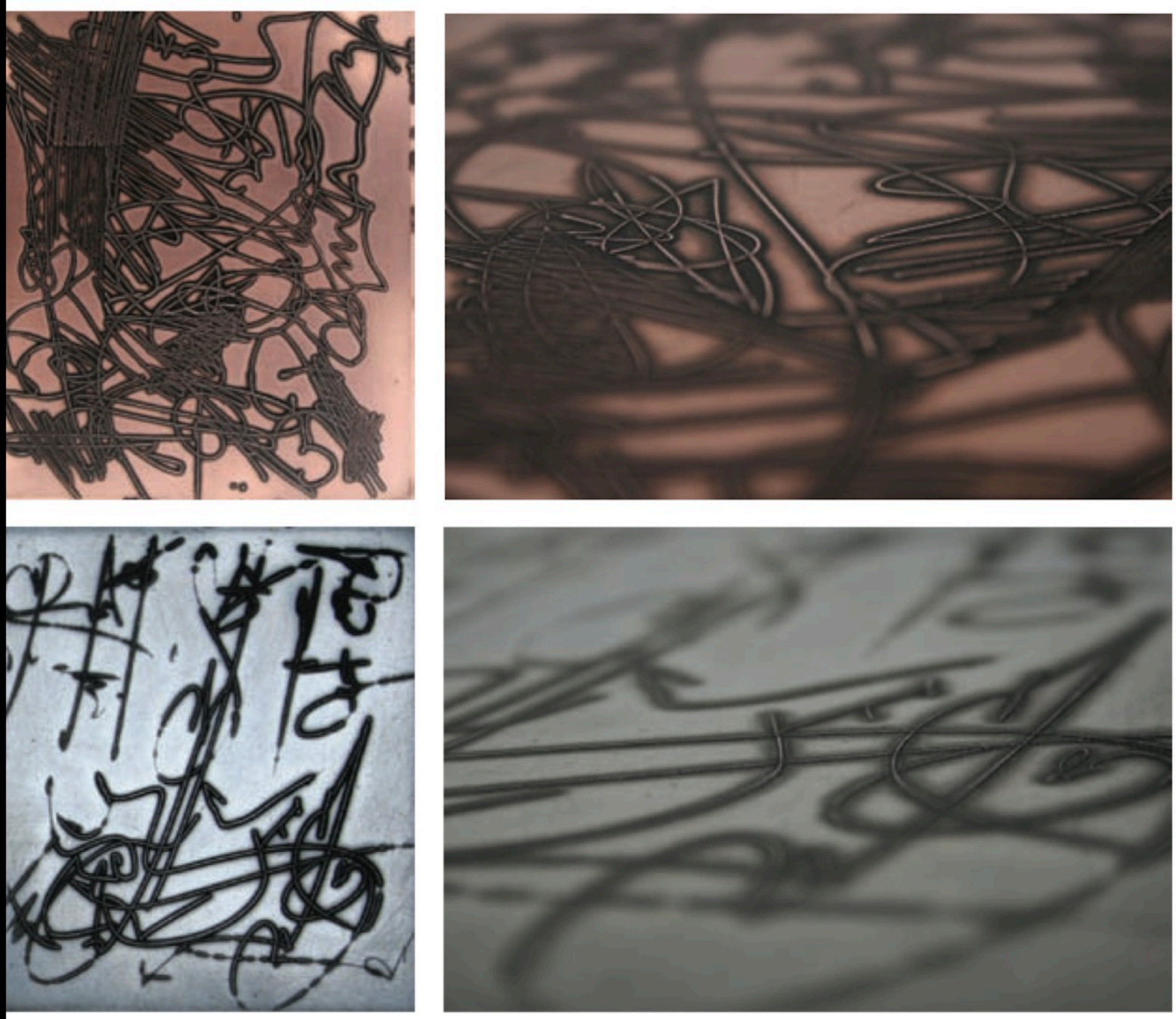
will lose metal at the same rate as it is acquired by the plate that is being galvanised.

Generally, the plate that is going to be galvanised, either entirely or partially, must be completely clean and degreased as any dirt or foreign particles will prevent the positive metal ions attaching themselves to the plate. This would leave a *crevé* where there should be micro dots of galvanised metal –an effect which may be exploited for expressive or graphic purposes but is undesirable in the present context.

Galvanised relief lines

In the initial brief overview of the history of electro-etching, it was mentioned that in the 1960s S. W. Hayter, of Atelier 17, Paris, France, was already aware of this method but that it was Cedric Green who popularised and applied it to modern electro-etching.

If we protect a plate with hard ground, draw lines on it with etching points, which exposes the metal below, place it at the cathode (-) and switch on, then the metal from the anode will be deposited in the



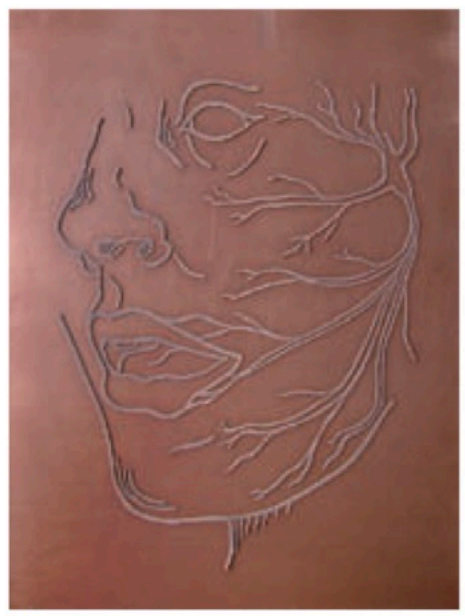
Copper and zinc plates and details of the galvanised lines. Pictures taken while inked, prior to printing.

lines which have been drawn, building a linear metal structure, like a miniature welded seam. When inked like a drypoint, this type of ridge or burr will print lines of ink deposited beside the galvanised lines, as if it were a drypoint. Unlike a drypoint, however, it is resilient to the erosion caused by the process of inking, cleaning and printing the plate for a longer time.

The plate is prepared as usual with the contact-strip, degreased, the hard ground applied and the drawing made with metallic etching points. For this technique it is necessary to ensure that the drawn lines are completely degreased. This is done by very briefly submerging the plate in a salt and vinegar solution, gently brushing the lines with a paintbrush and rinsing the plate with water before putting the plate into the electrolytic bath.

Degreasing lines electrolytically

There is a way to degrease the lines electrolytically: initially connect the electrode holding the plate to the positive pole of the power supply making it the anode with the donor plate temporarily the cathode, bite the lines with electrolysis for about 15 minutes; then reverse the electrical connections to the plates –donor plate (+) pole, plate to be galvanised (-) pole and switch on the power supply.



Copper plate with galvanised lines made by Luvier Casali.

We can take advantage of galvanised lines for expressive purposes in numerous ways. For example, the plate can be printed with ink or without ink to give an embossed effect.

When printing with ink, the ink should preferably be applied with a soft rubber spatula –as if it were an intaglio printing, the excess removed with pieces of smooth tarlatan, rubbing with the palm of the hand, and finally cleaning the inked plate with paper if sharp contrasts are desired. It will then be seen

that the galvanised lines hold the ink along their edges, as shown in the picture. If they are isolated lines they will give an extended "stain" of ink on either side of the galvanised line. This stain is created by the galvanised line on which the ink is spread, in such a way that if the lines are cross-hatched they retain the ink, forming a mass of colour.

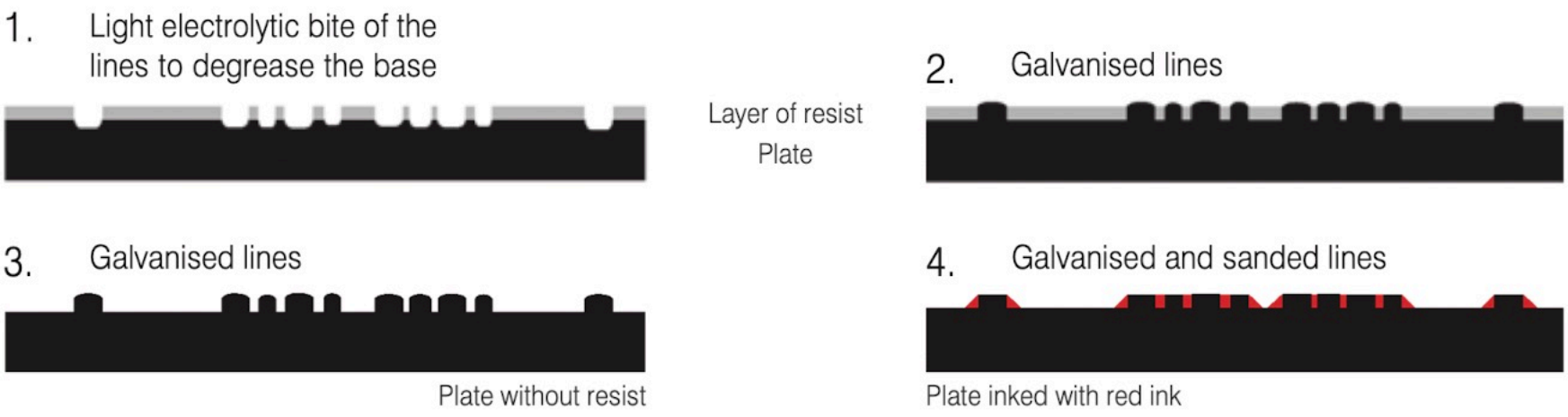


Illustration of galvanised relief lines.

These lines can also be treated to obtain better tonal results. Sand the lines with a fine grain of sandpaper and water if needed, the sandpaper supported on a hard, flat plug of wood. Alternatively the burrs can be burnished. The result will be a print of fine white lines outlined in a line of darker ink. This unique quality of the electrolytic application of *galvanised lines* is impossible to achieve in traditional etching. Applying welded seams to printable etching plates can give good results but the lines and strokes are crude in comparison with the expressiveness and elegance achieved with these lines in relief by electrolytic galvanisation.

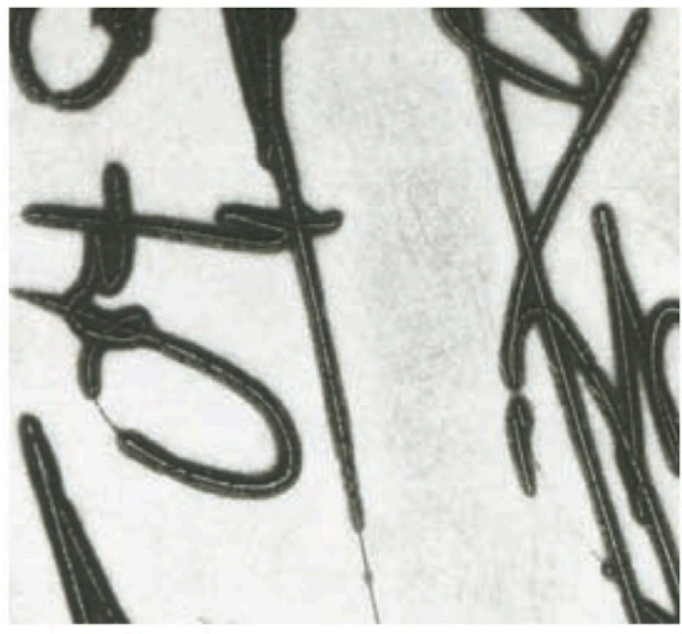
Electrolytes, voltages and galvanising times

Galvanising lines on copper plates

Use a solution with a concentration of 250 g of copper sulphate/litre of water and a low voltage of 1 V. This will generate interesting lines after 30 minutes, but the galvanisation can be continued for 60 minutes or more.

Galvanising lines on zinc plates

The concentration must be 300 g of zinc sulphate/litre of water and the voltage must be, 0.5 V. Again, this will produce interesting lines after 30 minutes, but the galvanisation can be continued for 60 minutes or more.



Prints of galvanised lines. On the left, copper plate, 200 g/l - 1 V, galvanisation of 60 mins plus four intervals of 30 mins. On the right, zinc plate, 300 g/l - 0.5 V, galvanisation of 60 mins plus two intervals of 30 mins, and detail of the same.

The procedure requires low voltage and long bite times. Experiment with this process. If you have reached this point after practising the earlier techniques, you will be able to work with this technique and gain the satisfaction of increasing your expressive options.

For example, the different methods of electrolytic bite can be combined on a plate on which you have already drawn –with galvanised relief lines. Alternatively line drawings, areas of electrotint or soft ground can be added with the techniques already described, obtaining unique, printable results as the following plate demonstrates.

Galvanised relief lines (on white) and electro-etching electrotint on copper plate: concentration 200 g/l - galvanisation 1 V - for electrotint 0.5 V. All with different intervals of time.

Galvanised tonal effects

This process of electroplating or galvanisation can also be used to complement and enrich the tone of electrotint generated by the electrolytic techniques outlined previously. For the basic procedure, first, the appropriate resist for your work can be applied and the plate electro-etched in the usual way to obtain lines and an electrotinted

surface, using all the steps needed. Next stop out the areas you want to protect from further processing and change the polarity of the plates as described above –the etched plate becomes the cathode. Then the plate is galvanised to accentuate the effect of the electrotint.

The effect of the galvanised micro dots produced by the metal particles stuck to the plate situated at the cathode can be used to print a darker tone. These micro dots in relief print as if they were a very fine grain of carborundum powder. Tones can also be manipulated by using stopping out strokes and cross hatching with oil pencils, lithographic or wax crayons to block the galvanisation.

It may be appreciated that various combinations of etching, galvanising, leaving the plate surface open, applying grounds, repeating processes can be explored to produce rich effects.

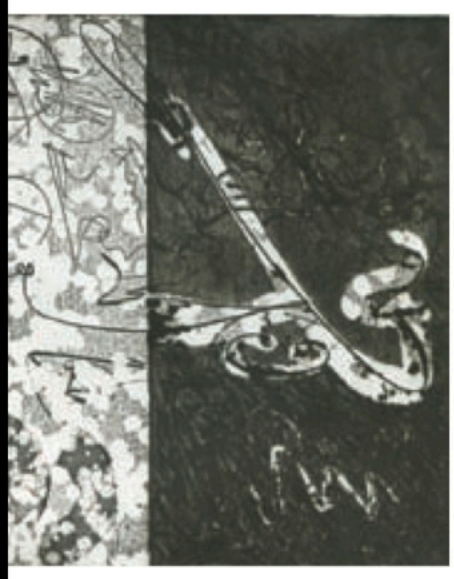
Galvanising electrotint on copper plates

The solutions must be more concentrated, 250 g of copper sulphate/litre of water, and a higher voltage of 1 V. After 30 minutes some tone will be visible, but longer bites, up to 120 minutes, are advisable.

Electrolytes, voltages and galvanising times

Galvanising electrotint on zinc plates

A solution with a concentration of 300 g of zinc sulphate/litre of water works well, but I have obtained better results with a concentration of 500 g of zinc sulphate/litre of water. Use a low voltage; 0.5 V, for long bites. Try with intervals of between 30 and 120 minutes.



On the left, copper plate, electrotint with graphite ink (light area), galvanised electrotint (dark area), resist with alcohol varnish, concentration 200 g/l - 1 V - two intervals of galvanisation of 30 mins. In the center, zinc plate, galvanised electrotint, concentration 500 g/l - 1 V - three intervals of galvanisation of 30 mins. On the right, zinc plate, galvanised electrotint, concentration 300 g/l - 0.5 V - four intervals of galvanisation of 30 mins.

Galvanising a copper plate combined with passive electro-etching of zinc

The unique features of the *passive electro-etching*, as described on page 85, allow a copper cathode plate to be galvanised at the same time as a zinc plate is etched using a copper sulphate solution as the electrolyte.

If the copper plate, which acts as a cathode, has been degreased and areas have been stopped out with resist, the bare areas of the metal will be galvanised with micro dots –the minute copper particles deposited from the electrolyte. This plate can be printed. Etch and galvanise with an electrolyte of copper sulphate with a concentration of 250 g/litre of water for 120 minutes –this can consist of a series of etching and stopping outs if desired rather than just one run.

Mezzotint on a galvanised plate

Another surprising application of galvanisation for artistic purposes is the creation of a pseudo mezzotint obtained by galvanising the plate, or part of it, with an even stipple. Of course, it will not achieve the velvety black impression of a plate rocked traditionally with a mezzotint rocker. However, if the galvanisation has been carried out correctly, the stippled surface of the plate will be sufficiently solid and rough to be able to obtain multiple tones. As with traditional mezzotint methods, these are obtained by scraping and burnishing the metal adequately with flat, pointed or curved scrapers and burnishers in order to achieve light and shadow. I recommend this galvanising technique to mezzotint enthusiasts, it is very effective. Conventionally, marking a plate with roulettes or a mezzotint rocker can take hours and a huge amount of effort. With the *galvanised mezzotint method* it is the electricity that does all the "donkey" work, leaving the more interesting part to the artist: "revealing the image" with his tools.

It is best to use copper plates as zinc will provide fewer copies. Prepare the plate with the contact-strip and degrease it properly with a mix of vinegar and whiting or another method –see section *Degreasing the plate* on page 45. However, before galvanising, I recommend that you degrease with electrolysis for 15 minutes, as explained for galvanised lines, so that the surface of the metal is completely clean which aids the electroplating process. This ensures that the metal will

adhere to the plate in a regular manner, producing even micro dots which will print a deep black tone.

Once the plate has been degreased by electrolysis, you can proceed with the method of galvanisation below.

Galvanising micro dots on copper plate for mezzotint

Use a solution with a concentration of 250 g of copper sulphate/litre of water and a low voltage of between 0.5 and 1 V. The distance between the electrodes should be around 6 cm. It will have to be galvanised for around 4 to 8 hours to get a decent stipple. As with the previous methods, take the initiative: test and experiment until you manage to get the process that suits you.

Electrolytes, voltages and galvanising times

Copper plate, mezzotint from galvanised micro dots, concentration 250 g/l - 0.5 V, galvanisation of 12 hours. 1st and 2nd stage proofs. Mezzotint made by Ana Mª Rebollo.

Lithography on a galvanised plate

Lithography has been extremely important in graphic art since its invention in the 18th century. Lithography is based on the fact that water and grease do not mix. For those unfamiliar with traditional lithography, it includes the following principal steps (there are other ancillary steps which have not been included):

- A porous limestone surface is given a texture or "grain" by rubbing it with carborundum –a process called graining
- A drawing using grease or wax based materials in solid (crayons) or liquid (tusche) form is made on the surface –this drawing becomes chemically and physically embedded into the stone's surface

- Those parts of the surface without an image are "de-sensitised" to oil based ink by applying a thin film of gum Arabic and nitric acid which is allowed to dry
- A wet sponge is used to dampen the surface with water which will be repelled from the greasy image but will lie on the non-image areas
- Oil based ink is rolled onto the stone –it is retained by the greasy image but repelled by the non-image areas– building up the ink on the greasy image requires a number of applications until there is sufficient ink; the stone must be kept damp throughout
- The damp areas are dried off and then a print can be taken using a Lithographic press.

In the 20th century artists and etchers developed the lithographic technique, substituting the stone base with industrial technological supports, such as photosensitive plates or the aluminium used in printing by the offset system. These fine grained aluminium plates allow etchers to carry out lithography without stone, using the traditional lithographic techniques to draw and ink the plates, and the same etching presses used in intaglio methods to print them, rather than using specific presses for printing stone lithography. Since the majority of workshops and etchers do not have stones or lithographic presses available this approach offers an alternative. The lithographic system using micro-granular aluminium plates allows more etchers access to the lithographic technique, which has spread rapidly among etching workshops because of its acceptable graphic results, ease in handling and reduced cost as compared to traditional methods.

Using a fine grained plate with micro dots generated by galvanisation is yet another option offered by electrolysis. In *Taller de Gráfica el Topo*, Zacatecas, Mexico, they took the initiative to grain the surface of an iron plate by galvanisation after which they drew on it and carried out the usual processes for lithography on metal, successfully obtaining lithographic prints.

During the electro-etching course I gave in the summer of 2011 at the *elmonodelatinta* workshop in Madrid, Spain, I had the opportunity

to try out this technique. Miriam Cantera, who is very familiar with the technique of lithography on micro-granular aluminium plates, carried out a lithography after we galvanised a copper plate.

To galvanise micro dots on a plate that can be worked on like a lithography, follow the steps outlined above for preparing a plate for galvanised mezzotint.

Galvanising micro dots for lithography on copper plate

Use a solution with a concentration of 250 g of copper sulphate/litre of water and a low voltage of between 0.5 and 1 V. There should be a 6 cm distance between the electrodes. The plate will have to be galvanised for several hours to achieve an adequate grain: between 4 and 8 hours approximately.

Electrolytes, voltages and galvanising times

Once the plate has been microdotted sufficiently, draw on it with lithographic pencils or bars and lithographic inks. Rub the surface of the plate with a little talcum powder and proceed to treat the plate with a mixture of gum arabic and a few drops of nitric acid. Rub this mixture on the surface of the plate with a sponge for a minute so that it is slightly sticky and allow it to dry. Rub the surface of the plate again with a damp cloth and a little turpentine until the image appears. (Use mask and gloves for protection if necessary). Apply a thin layer of liquid bitumen and allow it to dry; then remove the layer of gum arabic with water and proceed to print with *Charbonnel's Noir a monter*, keeping the plate damp with water.

Drawing the plate

Copper plate, lithography on micro dots with electrolytic bite (thick grain), concentration 250 g/l - 0.5 V - 3 hours 30 minutes.

A surprising piece of information: when we carried out the

galvanisation we obtained a fine and regular electrotint over the entire surface of the plate, but we also noticed that the plate that was at the anode, the *donor plate* had been corroded uniformly over its entire surface except at the edges, although with a thicker grain. We then cut off the edges and carried out the lithography as shown in the picture. So it is possible to obtain a micro-granular plate for lithography by galvanisation at the cathode (fine grain), and by corrosion at the anode (thick grain).

This technique has the advantage that it allows etchers to "grain" their own lithographic plates by recycling old plates. However, it also has a disadvantage: it uses turpentine and a few small drops of nitric acid, substances that we want to avoid with the techniques outlined in this handbook. In spite of this, I have decided to relate this process as I think it could be interesting for etchers to experiment with it. I think that with experience and everyone's participation, we will find ways to improve the process and avoid using the acid.

This is yet another graphic application that demonstrates the versatility of electrolytic methods.

Galvanography or Electroplating

The well known traditional technique of *collagraphy* is a method of creating an uneven surface on a "plate" so that it can hold ink to allow the plate to be printed. The plate may be non metallic, for example, made from cardboard with media such as fabric, carborundum or paper glued on.

The innovation to be described below takes such an uneven, non-metallic "plate" and uses it as a mould to create a metallic, negative copy of the surface which can then be used for printing.

The advantages of this approach is that the metal copy is stronger than the original "plate" and additionally it allows a printable plate to be created from a mould made with materials that cannot normally be printed –see *Preparation of the mould* on page 105. The method which is used may be understood from the knowledge already acquired from the manual –see section *Principles of galvanising* on page 93.

In the present case, the non metallic mould forms the cathode of the electro-etching cell; it is this mould which will be galvanised. To do this, one trick is required: the surface of the mould must be given an electrically conducting coating (see below). Unlike electro-etching, the anode does not have to be coated with a resist since its function is to complete the electrical circuit and to provide metallic ions to the electrolyte. Once the mould is removed, the covering of metal will faithfully reproduce the original mould.

Contact-clips

In order to connect the mould to the electrodes I have used contact-clips (see pictures) that I have made with some small, but very strong, crocodile clips. They are made of plastic so they can be submerged in the electrolyte to hold the mould in place. Attached to the mouth of each clip are two small hinged pieces of plastic. On one of them, I have stuck a small copper plate 1 mm thick, 2 cm long and 1 cm wide. On the same side of this small plate, I have soldered a copper wire insulated with plastic which will carry the current to the mould from the electrode connected to the power supply. I have protected the tin solder by completely covering it with epoxy glue so that it will not be corroded by the electrolyte. Of course other methods of connecting the electrical supply to the mould may be possible.

The contact-clips are used to hold the plate in place while it is submerged in the tank and to conduct the electricity from the power supply to the surface of the mould, which is covered with graphite powder.

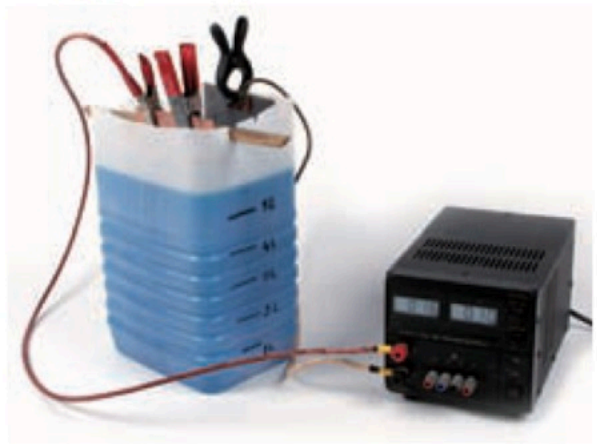
Contact-clips:
Wire soldered to the small copper plate and contact-clip (left).
Contact-clip ready, the solder insulated with epoxy glue can be seen (right).

Preparation of the mould

Given that it is going to be submerged in liquid, the mould must be made from a waterproof base. If this it is not the case, it is necessary to waterproof it with varnish or paint. We can draw on the base with intaglio ink, apply wax or plaster, or even make a collage with materials of different textures, cardboard, papers, fabrics, etc. Once the mould is prepared, if there are materials that are very porous, and there is no wish to print them in too dark a tone, they can be varnished. Alternatively, if the more porous textures are of interest, they can be used without protection, that is to say without varnishing, so that they may store a great deal of ink or because the plate is going to be printed in relief or embossed.

Once the mould is finished, it is necessary to apply a layer of graphite powder to the surface. Graphite is an electrical conductor and allows the current to flow, attracting the particles of metal from the electrolyte to the mould. The graphite is applied as follows:

- Prepare silicone liquid wax or a mixture with one part water and three parts acrylic base –I usually use *Primal Acrylic Medium*
- Apply a thin layer of the preparation to the surface of the mould with a soft haired paintbrush, leave it to dry a little and while still sticky, cover the entire surface with plenty of graphite powder then leave to dry completely for a few minutes
- Carefully remove the excess of graphite with a dry paintbrush
- If any area of the mould has not been covered with graphite, then repeat the process on the areas that require it.



Steps in the process of galvanography. From left to right: the mould, a methacrylate plate with different materials; application of latex and graphite; the mould with the layer of graphite; connecting the mould; the galvanising tank with a recycled copper plate in the anode.

It is advisable to use a protective mask to avoid inhaling the graphite powder. Once the excess powder has been removed from the mould, it is no longer necessary to use the mask while handling and submerging the mould in the electrolytic tank nor during the following steps.

Galvanisation with copper

Prepare the electrolyte with a solution of 250 g of copper sulphate/litre of water. The voltage used should be low, between 0.5 and 1 V.

Once the mould with a suitable electrical connection has been prepared, submerge the mould in the electrolytic tank ensuring that the electrolyte wets the copper on the contact-clip. Then connect it to the cathode (-) making sure that the surface covered with graphite is facing and parallel to the anode (+). At the anode, I recommend that you simply place one or more strips of copper. At the end of this chapter some suggestions for using recyclable metal at the anode can be found.

Connect the power supply and adjust the voltage –I prefer to galvanise with 1 V. The amperage is low at the beginning of the process, but as galvanising progresses and metal is accumulated on the cathode, the amperage will gradually increase. The process requires a long period of time. Exactly how long will depend on the dimensions of the plate: between 24 and 48 hours of galvanisation to obtain approximately a millimetre thickness. This process is slow, but efficient and safe.

When connected to the power supply the current flows and the metal is deposited on the surface of the mould. The metal particles will begin to spread out from the contact-clips. During this process, after 30 minutes to an hour, it is a good idea to disconnect the power supply, carefully remove the plate, and check that the galvanisation is working properly. If metal particles have not spread from the contact-clips to the area surrounding them, it means that there is no electrical connection between the clips and the graphite surface. Ensure that it is properly connected, return the mould to the tank and continue to galvanise. This procedure can be repeated every so often to check that

the process is galvanising effectively. If some area of the mould has not been galvanised, it will be necessary to re-apply a little graphite powder to these areas to facilitate the attraction of the metal so that it will eventually cover the surface of the mould completely. Change the position of the contact-clip to facilitate the galvanisation, if it is necessary.

Several pictures showing the progression of the galvanisation process until the mould is completely covered. A concentration of 250 g/l – 1.5 V is used. From left to right: galvanising the mould in the beginning of the process, after 20 minutes (0.8 A); galvanising after 40 minutes (2.0 A); details of galvanisation; galvanising after 3 hours (2.3 A); galvanised mould after 18 hours (2.5 A); galvanised mould.

Moulds that produce a deep “V” –shaped relief - an acute angle– will be difficult to galvanise at the deepest point, so try to avoid this.

After a substantial amount of time has elapsed, metal, approximately between 0.5 and 1 mm thickness, will have formed on the surface. Once the mould has been checked to ensure that it is com-

pletely covered with metal, take it out of the tank, put it in the rinsing tank, remove the contact-clips, wash thoroughly and leave it to dry.

An *edge effect* may occur during the process of galvanisation and is caused by excessive accumulation of metal at the edges of the plate, these growths are known as *dendrites*. This effect can be avoided by keeping the voltage low and separating the two electrodes, that is to say, increasing the distance between the positive and negative pole. While a distance of 6 cm between the electrodes is sufficient for etching with electrolysis, I have found that for this galvanisation, a greater distance between the poles provides a more even layer of metal, and to a great extent, avoids the edge effect. If the tank is large enough, use a minimum distance of 10 cm.

Edge effect in galvanisation.

Levelling the plate

The plate created by galvanisation is the negative of the mould –the inner surface next to the mould is the printing surface. Before separating the mould from the newly formed plate to enable inking up and printing, it is necessary to form a flat base for the plate by filling and levelling the external surface.

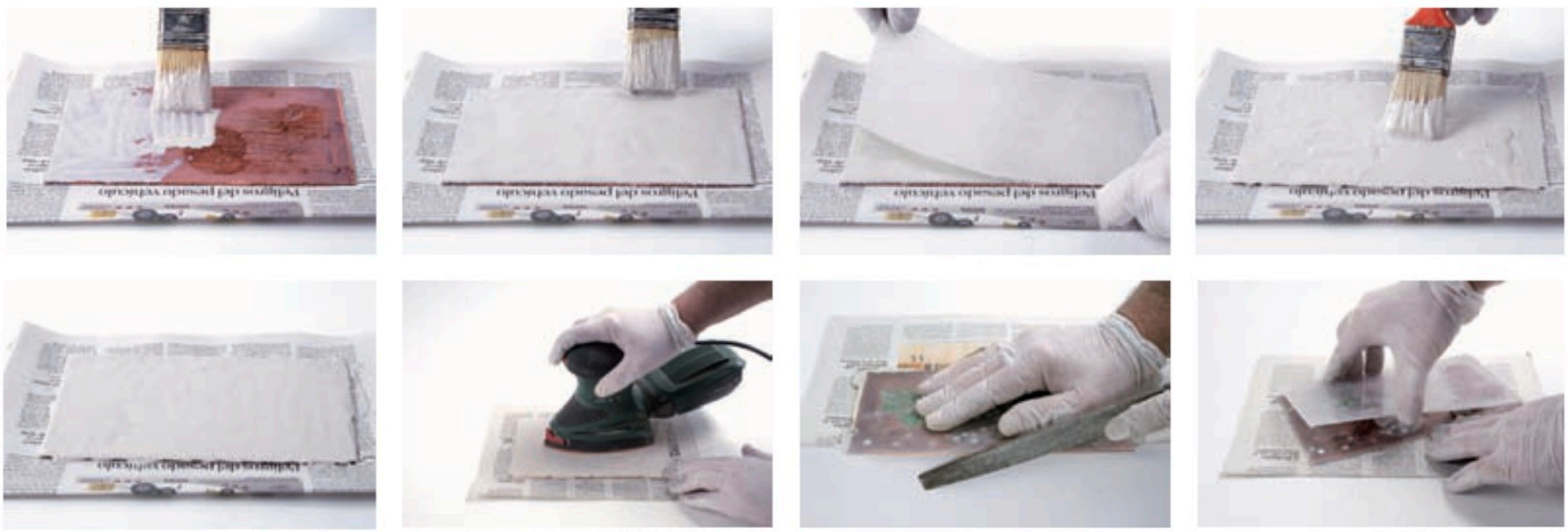
The irregularities in the relief of the galvanised surface are levelled out with a resistant filling material, this avoids the plate becoming distorted under the pressure of the etching press during printing.

The back of the plate should be filled with odourless epoxy resin, and the surface levelled with a spatula. Peter Sjöblom, from Atelje Larsen, fills these irregularities with melted tin, then files them. Odourless acrylic resin which is supplied as a two component mix, a liquid and powder, can also be used. Prepare the resin in the proportions recommended by the manufacturer, mixing them well. Apply it

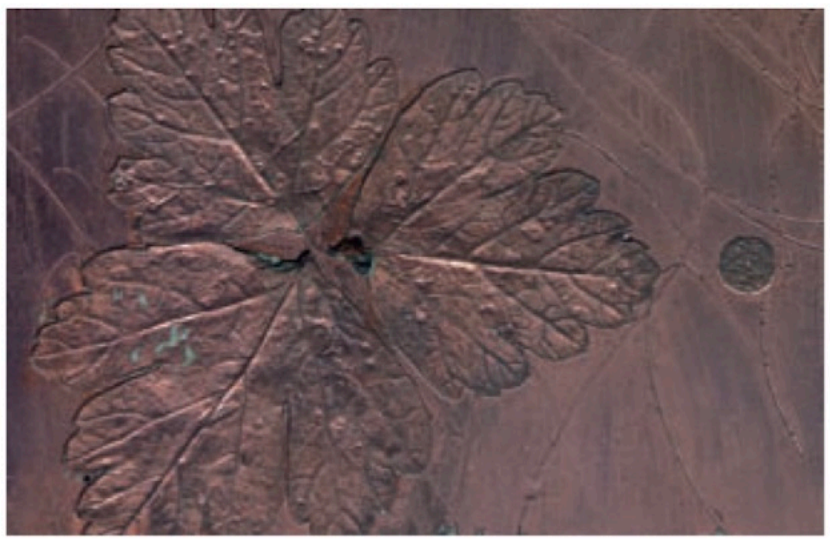
with a large paintbrush or spatula directly onto the metal, ensuring that it fills the different reliefs properly –avoiding bubbles. I recommend that you reinforce this filling with a fine fibreglass mesh that will give the plate flexibility and ensures that it does not break under the pressure of the etching press. Apply another layer of resin over the fibreglass mesh. This resin dries in half an hour, but it needs to be left to dry for 24 hours before it can be worked on. Polish the surface with emery paper or an electric sander until it is smooth and flat; cut and file the edges of the plate if necessary, and finally, separate the plate from the mould.

The result will be a plate similar to a collagraph, but with the strength and advantages of a noble metal like copper, able to withstand long prints without distortion.

Steps in the process of levelling the back of the new plate and separation of the mould.



From left to right: Applying the resin; setting the fibreglass mesh; covering the fibreglass mesh with resin; the back of the plate covered; sanding and levelling the plate; filing the edges of the plate; separating the mould from the newly formed plate.



The plate obtained from galvanisation (left) and detail of the plate (right).

The plate shown in the picture at the end of page 109, left, was a failed proof. The layer of galvanised copper was broken when I separated it from the mould. I suppose that one or a combination of the following reasons was the cause of this failure: first, the electrolytic solution might have not been properly cleaned from the surface of the plate when the process of galvanisation was finished, this could have prevented the resin from sticking securely to the back of the plate. Secondly, the galvanised metal layer was too thin; thirdly, a poor application of graphite powder let the "acrylic solution" make contact with the copper. The copper layer and the mould were held firmly together when I tried to separate them.

Copper plate and proof printed in intaglio and relief with roller.

Now you can print the plate with different systems: dry as with embossing; intaglio inked, or with rollers and inks of different viscosities. The relief plates obtained with this process are very suitable to print with the system known as *Roll Up*.

You can also continue working on the plate with different methods, for example drypoint or any other electro-etching technique discussed in this handbook. I admit that it is a long process, but it is not difficult. I assure you that you will be surprised by how accurately this method replicates the textures used.

Silicone moulds

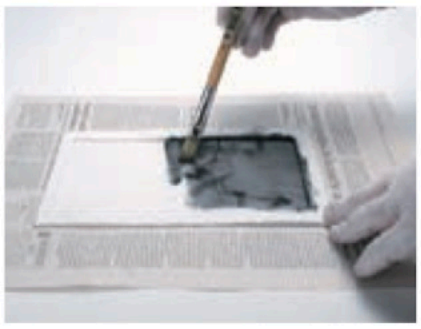
Up to now a metallic plate has been formed that is the negative of the collage-mould. By using the modern two component silicone acrylic liquids (resin and catalyst) employed by modern sculptors, a negative of the mould can easily be obtained. Then this silicone mask can be used as the mould for the galvanisation process to produce a metal plate that is a positive of the original mould. This silicone also reproduces faithfully the different textures used.

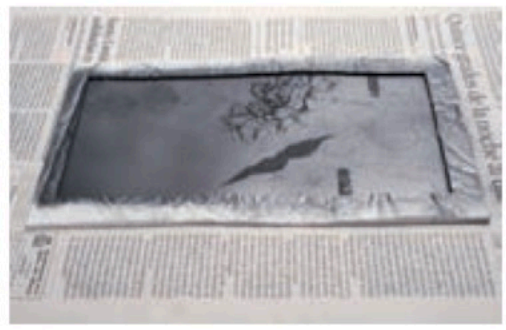
Two brands of silicone acrylic liquid.

The silicone is mixed with the catalyst in the proportions recommended by the manufacturer. The silicone liquid is then applied to the mould with a large paintbrush which will easily fit into the holes and reliefs –avoid the bubbles. Once the silicone is properly cured it will separate from the mould extremely easily. Certain materials, like paper, may stick to the silicone and will have to be removed with water and by rubbing.

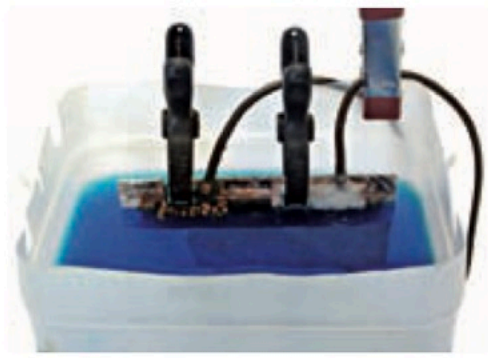
Bear in mind that the silicone mould requires support when submerged in the electrolytic tank: a plate of methacrylate the same size as the mould can be stuck to the reverse side. This will provide rigidity to the silicone mould, which although waterproof, is also flexible and can become distorted by the weight of the metal during galvanisation. Although, as before, the face that is going to be galvanised must be covered with a fine layer of graphite powder, there is no need to apply the acrylic solution because even when dry the silicone has a slightly sticky surface which enables the graphite to be applied directly with a soft paintbrush. The silicone mould is secured with the contact-clips making sure that there is electrical contact with the graphite covered surface.

Steps in the process of silicone mould. From left to right: The mould, a methacrylate plate; applying the silicone liquid; separating the silicone from the mould; silicone mould; a plate of methacrylate stuck to the reverse side of the silicone mould; (the process continues on the next page).





As before the mould is placed in the tank, the contact-clips connected to the electrodes, and electrolytic galvanisation applied for the period of time necessary for the size of the surface that is to be galvanised. A plate of metal that reproduces in positive the textures and drawings of the mould will be created.



Following the steps in the process of silicone mould. From left to right: Applying graphite powder; mould of silicone with graphite power; mould with contact-clips; the mould in the tank.

Before separating the plate from the mould for printing, the process of filling and levelling the reverse side must be carried out –see section *Levelling the plate* on page 108.

This silicone mould is so resistant and waterproof in the electrolytic bath that it can be re-used: apply graphite powder and galvanise it again. Surprisingly, we can obtain reproductions of the mould, meaning multiple identical plates creating a multiple object of art.

This technique is not electro-etching as it is not etching a plate, rather it creates a plate in "bas-relief" that can be printed as an intaglio plate with a roller or dry as embossing, as has already been outlined. In addition, the method provides specific graphic advantages, given that it can also be used to galvanise three dimensional objects, sculptures, etc. –see *Electroplating or electroforming* in the *Glossary*.

Galvanography or *electroplating*, like *electrotyping* or *galvanoplasty*, is an application of an electrolytic technique that would need a separate handbook dedicated to it. Lack of imagination is the only limit to this experience that has much promise for the future.

Recycling used copper plates and scrap

The various techniques based on galvanising the plate at the cathode electrode allow old etching plates to be re-used as the anode material and so makes responsible use of what are becoming expensive and scarce raw materials. Recently the price of copper, an almost essential metal for our work, has increased by 300%. Fortunately, galvanisation offers us the opportunity to save metal by recycling plates that have

already been printed –a melancholy souvenir for those etchers that store them once they have been used, but a useless hoard of metal for others. We can use (recycle) these plates as *donor plates* connecting them to the anode (+), where they will provide the metal that will be deposited at the cathode (-), creating new plates for galvanisation. Consequently, it is not necessary to buy new copper plates to put this method into practice: spare strips from cutting plates or any other bits of old copper can be recycled.

Recent developments and work in progress

This section has been included because the techniques outlined are the result of experiments that have not been concluded so there remains ample opportunity for experimentation and developments which may lead to modifications, improvements and progress in the techniques to be described. It is a section that I consider necessary as it shows, once more, the graphic versatility of the electrolytic processes and the benefits that they can offer etchers who want to experiment.

Photopolymer resists

Photosensitive emulsions and photopolymer films originally developed for the electronics industry and commercial printing can be used as resists for etching plates of copper, zinc, or iron by conventional methods or electro-etching. The photopolymer process is an effective, safe technique in its own right for etching all types of images. These resists are highly valued by contemporary artists as not only are they safe to use, but they also allow a photographic image –whether or not it has been manipulated by digital or manual processes– to be transferred to metal plates, and subsequently printed like intaglio plates. I consider its use with electro-etching to be especially suitable for those etchers who want to take advantage of this feature while being able to etch safely with electrolysis.

Although there are a number of publications in several languages concerning the technique, it may still be unfamiliar to the traditional etcher. For this reason and to keep this introduction self-contained, I will first give some background information on using these methods.

I recommend that those etchers who are not familiar with this technique but are interested in using it with electro-etching should attend a photopolymer workshop. Those already familiar with it will find its application to electro-etching straight forward. It is likely that the etcher's first experience will be in an "open access" print studio which will have the requisite ultra violet (UV) exposure unit, dark room, press and drying unit required. Home made versions of the equipment can be made but care must be taken when using UV light.

Background to photopolymer techniques

These materials are made with polymers which change their properties upon being exposed to ultraviolet (UV) light. The process consists of applying a photosensitive emulsion or photopolymer film to an etching plate. The image to be etched is drawn, painted or photocopied onto a transparent film or sheet, for example a *Mylar* film or acetate sheet as used for overhead projection presentations. This sheet with the image is placed on top of the plate which is then exposed to UV light.

Where there is no image, the UV light passes through the sheet and hardens the emulsion or photopolymer film underneath. On the other hand, where the image blocks the UV light, the emulsion or film remains soft. When the plate is then developed, the soft areas are dissolved away while the hardened areas remain in place on the plate. Effectively a drawn image is impressed upon the polymer resist extending down to the surface of the metal which consequently is exposed so that it can be etched conventionally or, in our case, with electrolysis.

Transparent sheet/film – image sheet

It is important to realise that the final impression greatly depends on the quality of the image –an opaque image, in positive, on a transparent base. The photopolymer process only recognises opaque (darks) or transparent (whites) areas. Black and grey marks, whether drawn or printed, obstruct the light.

Dark areas and tones are created on the final printed image by ensuring that the corresponding areas on the etched plate have "tooth" of varying density in much the same way as traditional aquatint.

Depending upon the nature of the original artwork, either computer software may be used to manipulate a scanned image, effectively splitting it into a half tone image which is then used in the process, or a "double exposure" may be used which first exposes the plate using a so called *aquatint screen* before exposing with the image. Further details are given below.

At the end of the photopolymer/electro-etching process the original image marks will be transformed into tiny etched dots in the plate which will hold the ink for intaglio printing. For our purposes the image can be photocopied, printed, or drawn directly onto ink jet transparent paper or transparent matt polyester (*Canson*), for example.

As mentioned, if the initial image is digital (photograph, scanned image, retouched and manipulated photograph, etc.) it must first be converted to an appropriate form for the process: the image must be decomposed into a matrix of fine dots rather like a photograph in a newspaper. With a digital imaging software package, the image is transformed by way of "grey scale", the parameters of brightness/ contrast, levels, size, etc., and it is then printed with black ink on a transparent sheet suitable for ink jet. An alternative approach which does not require the modification of the initial image is to use a double exposure with an aquatint screen (see below).

To prepare the "image sheet" by hand, use a sheet of transparent matt polyester paper on which you can draw with a great variety of opaque materials: Indian ink, acrylic paint, lithographic crayons, or graphite pencils, for example. Another way to obtain the image sheet is by combining a digital or photographic image printed on a transparent sheet and then adding a hand drawn image. If the image is drawn onto the transparent sheet by hand, or if it is a combination of photography and ink drawing, it is necessary to decompose the transferred image on the plate into a matrix of fine dots. This can be done by first exposing the plate using a film which has an image of random "dots" (sometimes known as an *aquatint* or *stochastic screen*), effectively creating a potential microdotted surface as its name implies. Then a second exposure is made with the image sheet replacing the

aquatint screen.The combined effect when the plate is developed is to break up continuous dark lines or areas into lines/areas with fine micro dots structure. If this procedure is not carried out then the darkest areas will develop *crevés*.

The smallest areas of a drawing may not resist the electrolytic action on the emulsions and photopolymer films. For this reason, to avoid *crevés* in areas where you want to get deep blacks, when working with photopolymers it might be advisable to expose the plate to the light first with the *aquatint screen* and then expose it with the film containing the image as described above.

Electro-etching with photosensitive emulsion

The photosensitive emulsion *Photo Imageable Etch Resist* is a dense acrylic paste composed of polymers which change their properties when exposed to ultraviolet light. It can be handled in areas of subdued light in the workshop without the need of a safelight.

Once the plate to be etched has been degreased with vinegar and salt, spread the emulsion with a foam roller, trying to apply a thin and even film. It should be dried with hot air, avoiding the light, for 10 minutes at 25ºC. Once dry, it will be ready to be exposed to the UV light.

It is possible to improvise a "dark drying room" by using a cardboard box with holes in the side so that a hot air dryer can be mounted to provide an air flow for drying. The box should be large enough for the plate to fit in comfortably and a black cloth can be used to cover the box to exclude light. Of course it is important to ensure that there is sufficient airflow through the box and that nothing overheats. When the dried plate is removed from the dryer it should be placed in a folder or envelope to exclude the ambient light prior to exposing the plate.

Exposing the plate

A golden rule when exposing the plate is that the side of the transparent sheet on which the image is drawn or printed (dull rather than shiny in appearance) should be in contact with the polymer emulsion. If you put the image sheet on the wrong way round, the final image will be inverted.

If possible, a professional exposure unit should be used to ensure that light cannot enter between the film and the plate –this avoids blurring. Exposure time depends on the light source: between 45 seconds and 2.5 minutes.

An alternative approach is to use direct sunlight: you can sandwich the plate and the film between two sheets of glass, fastening the glass with clips before exposing it to the sun. This method of exposure should only be used for simple images. When using sunlight remember that the direct light from the sun is more intense than the light in an exposure unit. In the summer and in "full sun" the exposure time could be 30 seconds, but if it is winter and cloudy it must be exposed for 10 or 15 minutes. In either case, it is not easy to predict.

Developing the plate

After exposure to light, the image should be developed in a solution of 50 g of sodium carbonate (washing soda) per litre of water. Put the plate into a tray with the developer. The polymer which was not hardened by the UV light will dissolve. When the image starts to appear, rub gently with cotton wool –wearing latex gloves– until the image can be clearly seen; this will take approximately 1 minute. The plate must be developed until the polymer in the "image areas" has been dissolved away to expose the bare metal. Then wash the plate well with clean water and dry it with hot air. Finally, fix the emulsion by exposing the developed plate to ultraviolet light once more for about the same time as originally used with the image sheet. The final hardness which is required depends on the aggressiveness of the mordant, which for electro-etching is rather strong. The bare metal of the plate that will be etched can be clearly seen.

Electro-etching on copper plate with photosensitive emulsion

Once the plate has been developed, it is ready for the etching process. If the emulsion has been properly hardened by the ultraviolet light, it will be resistant enough for the plate to be handled –but with care. Proceed as for the previous electrolytic processes: attach the contact-strip on the back of the plate, degrease in a tank with vinegar and salt, and finally, place it in the electrolytic tank.

Electrolytes, voltage and bite times

The electrolyte of copper sulphate can have a concentration of between 160 and 200 g/litre of water and a voltage of 0.5 V should be used. For the proofs shown below with plates of 20 x 15 cm the amperage was between 0.8 and 1 A and the bite time was 60 minutes at intervals of 15 minutes.

Proofs can be printed without removing the emulsion so that further etching can be carried out afterwards if required. However, before the final printing, the emulsion must be removed because any marks or the smallest bits of emulsion will lift, spoiling the work.

Once the etching is complete, the emulsion can be removed by submerging the plate in a solution of 4 or 5 tablespoonfuls of caustic soda (sodium hydroxide) per litre of water. Finally, after washing the plate with water and drying it, it will be ready for printing.

Proofs with copper plate protected with photosensitive emulsion. On the left, 200 g/l - 0.5 V - 1 A - three intervals of 15 mins with stop-out + 15 mins + 30 mins. On the right, photolith film with irregular pattern printed with an Epson plotter (left); photolith with pattern from print (right), 200 g/l - 0.5 V - 1 A - 60 mins - two intervals of 30 mins without stop-out . These proofs were carried out thanks to the invaluable contribution of Juan Lara, artist, etcher and expert in this process.

Electro-etching with photo-polymer film

This photopolymer film, created and used industrially to make electronic circuits, flexography, orthodontology, printing, etc., is made from polymers which, like the photosensitive emulsion, change their properties when exposed to ultraviolet (UV) light.

Photopolymer film

The film can be obtained in specialist art material shops. It consists of three layers: the photopolymer substrate is sandwiched between two sheets of protective, transparent *Mylar*. It must be stored away

from ambient light, and exposure must be avoided when handling. There are various brands on the market: *Photec Hitachi*, *ImagOn Ultra*, among others.

Laminating the plate

The first step is to laminate the plate, that is, stick the photopolymer film on to the plate in an area with a safelight. The following steps are required:

- The plate is cleaned, degreased and polished
- A piece of film slightly larger than the plate is cut –the film will naturally curl up
- The plate is placed on the workbench and lightly sprayed with water
- The *Mylar* protective layer on the inside surface of the curled up photopolymer film is removed –there is a knack to doing this!
- The film is held by the corners and the "open" surface is placed onto the plate –wrinkles in the film are likely to occur
- The top side of the film is lightly sprayed with water and then a "squeegee" (rubber blade) is used to smooth out the film, removing any bubbles and creases: start from the centre and move out towards the corners applying pressure (not too much)
- The plate is then turned over and placed on a cutting mat; the excess film is trimmed off with a scalpel using the edges of the plate as a guide
- Excess water is removed with a cloth; the plate is dried for several minutes using a hot air dryer and then placed in a light tight paper folder
- The folder is placed in a press, film face down, and run through the press several times with a pressure similar to that for a drypoint.

The film should now be adhered to the plate.

Transparent sheet/film and exposure

To transfer the image to the plate, the same types of film are used as for photosensitive emulsion. For the exposure of the plate you can also proceed as for that process, but do not remove the second *Mylar* protective sheet until after the exposure of the plate.

The exposure times will be between 30 and 120 seconds, depending on the nature of the image and the exposure unit. The usual thing is to first use a test plate to determine exposure times.

Developing the plate

The developer is a less concentrated solution than for the previous process: 10 g of sodium carbonate/litre of water. The *Mylar* sheet must be removed before developing. Once the *Mylar* has been removed, put the plate into the tray with the film facing upwards and rock the tray for a minute. Wearing latex gloves, rub the surface of the plate gently with a sponge for 2 minutes. You will be able to feel the relief of the hardened film with your fingertips through the glove.

It is important to ensure that the areas of photopolymer that have not been exposed to light due to the presence of the image are completely dissolved by the developing solution so that bare metal is exposed or the electro-etch will not work.

Remove the plate from the developing solution and then rinse with water, spray with white vinegar and gently rub the photopolymer film with a clean sponge, soaking it again with water. Finally, pat the plate dry with a paper towel and put it in the drying room with hot air for 10 minutes, and finally fix the photopolymer by exposing to ultraviolet light once more.

Electro-etching on a copper plate with photo-polymer film

Handle the plate carefully while preparing it for etching. As for the previous electrolytic methods, fix a contact-strip to the back of the plate, degrease it in a tank of vinegar with salt and place it in the electrolytic tank.

Electrolytes, voltages and bite times

The copper sulphate should have a concentration of between 160 and 200 g/litre of water. A voltage of 0.5 V should be used and will need a bite time of 30 - 60 minutes.

On the left, copper plate protected with photopolymer film, 160 g/l - 0.5 V - 60 mins, two intervals of 30 mins without stop-out. On the right, copper plate protected with photopolymer film, 200 g/l - 0.5 V - 60 mins, two intervals of 30 mins without stop-out. Pictures reproduced courtesy of the University of Vigo, Spain.

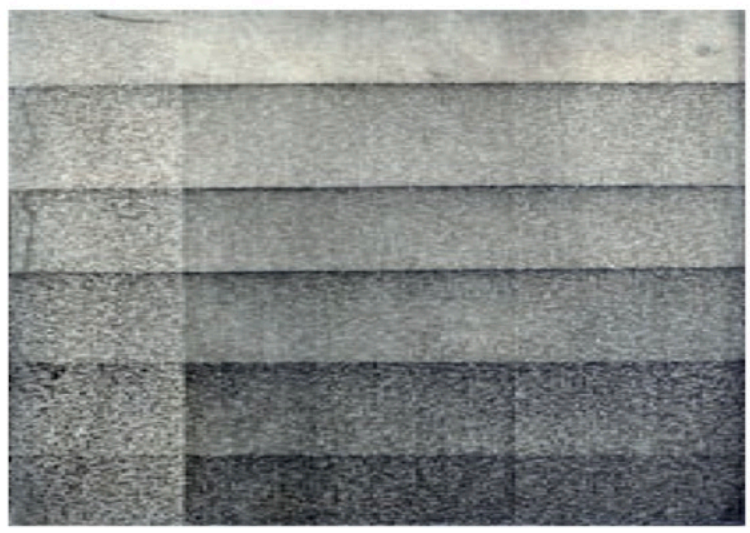
This experience of electrolytic etching with photopolymer film was carried out in collaboration with the investigation *group dx5* of the Faculty of Fine Arts at the University of Vigo, Spain, during the course of a seminar on electrolytic processes given in 2011.

Electro-etching copper plates using screen printing inks

As an aside, it is worth mentioning that in the above seminar we also had the opportunity to work with copper plates that were grounded with ink used for screen printing on cloth. Two blocks with cross hatching of different sizes were printed, which were then bitten with electrolysis. The screen printing ink resists the electrolytic action just like a ground.

Electrolytes, voltages and bite times

The electrolyte used was 200 g of copper sulphate/litre of water, the voltage was 0.5 V and the plate was bitten at 6 intervals of 15 minutes.



Copper plate protected with screen printing ink, drawing of three different patterns, 200 g/l - 0.5 V - 90 mins, in six intervals of 15 mins with stop-out. Picture reproduced courtesy of the University of Vigo, Spain.

Electro-etching on aluminium plates

I mentioned earlier in this manual that my past experiences of etching aluminium plates with electrolysis had been unsatisfactory. However, I think that it is interesting to discuss them and the *sacrificial metal* process used to etch aluminium.

Etching aluminium plates is a practice that has spread among art students because aluminium is cheaper than zinc or copper, and in addition, acid is not required as a mordant.

The *saline sulphate etch* is the mordant used to etch aluminium. It is a solution of copper sulphate and sodium chloride (common salt) with water. Several formulas of different concentrations used by Friedhard Kiekeben and Nik Semenoff can be found on the *Nontoxic Printmaking & Printing* website*. The results obtained with these formulas demonstrate their effectiveness, as does the number of artists –in Europe and in America– that use this mordant.

* See addresses at the end of this handbook.

In the Spanish handbook I published in 2008 I thought it was interesting to include the processes that use the saline sulphate etch to etch aluminium, zinc and iron plates, as it was a practice that was still not very widespread and gave artists who were not interested in electro-etching an alternative for etching in healthier conditions, avoiding acids.

However, the process presents several disadvantages: metallic residues are generated during the etching which can halt the etch if not removed; the mordant capacity of the solution becomes exhausted during the etching process and, consequently, more copper sulphate must be carefully added periodically; the exhausted solution has to be treated and the metallic residues disposed of.

It was to avoid these disadvantages that I was drawn to trying electrolytic etching with electricity on aluminium plates.

My first experiences using electrolysis to etch aluminium plates were carried out with electrolytes of aluminium sulphate with concentrations ranging between 100 and 200 g/litre of water and a voltage of 0.5 to 1 V, none of which produced useful graphic results.

In January 2011, the magazine Grabado y Edición nº 27, Madrid, published the article *Aguafuerte electrolítico sobre aluminio, hierro y*

acero (Electrolytic etching on aluminium, iron and steel) by Professor Francisco Hernández-Chavarría of the University of Costa Rica. This article describes a technique for etching these metals with electrolysis which he termed *sacrificial metal*. The idea for this evolved from a method of protecting metal pipes from corrosion by connecting them to an active metal which is "sacrificed" to corrosion (see below).

Sacrificial metal

In 1824 the English chemist Humphrey Davy discovered a process based on the reactivity of metals which consisted of joining easily corroded plates to a noble metal, or one of greater resistance, in order to protect this more valuable metal. The technique is called *cathodic protection* or *sacrificial anode*: the two metals form a galvanic battery, and the less noble metal, the one with a more negative electrochemical potential, corrodes (is sacrificed) leaving the other metal unaffected. This method of protecting noble metals with other, less valuable metals began to be used in industry. For example, the copper of a boat's hull or the steel of tubular structures exposed to a marine environment are covered with plates of zinc or aluminium, which suffer corrosion, thereby protecting the noble metals.

The technical process of etching aluminium plates by electrolysis, through sacrificial metal, differs from those that we have used up to now for etching copper, zinc and iron plates, in which both the cathode plate and the salt (sulphate) in the electrolyte were of the same metal as the plate to be etched.

In contrast, to etch an aluminium plate a solution of water and sodium chloride (common salt) is used as the electrolyte and a copper plate is used as the cathode.

Professor Hernández-Chavarría suggests using a mesh of recycled copper wire, and I can confirm its effectiveness. This approach differs from the previous active electro-etching methods since gases are produced and the composition of the electrolyte may be changed leading to residues collecting on the plates.

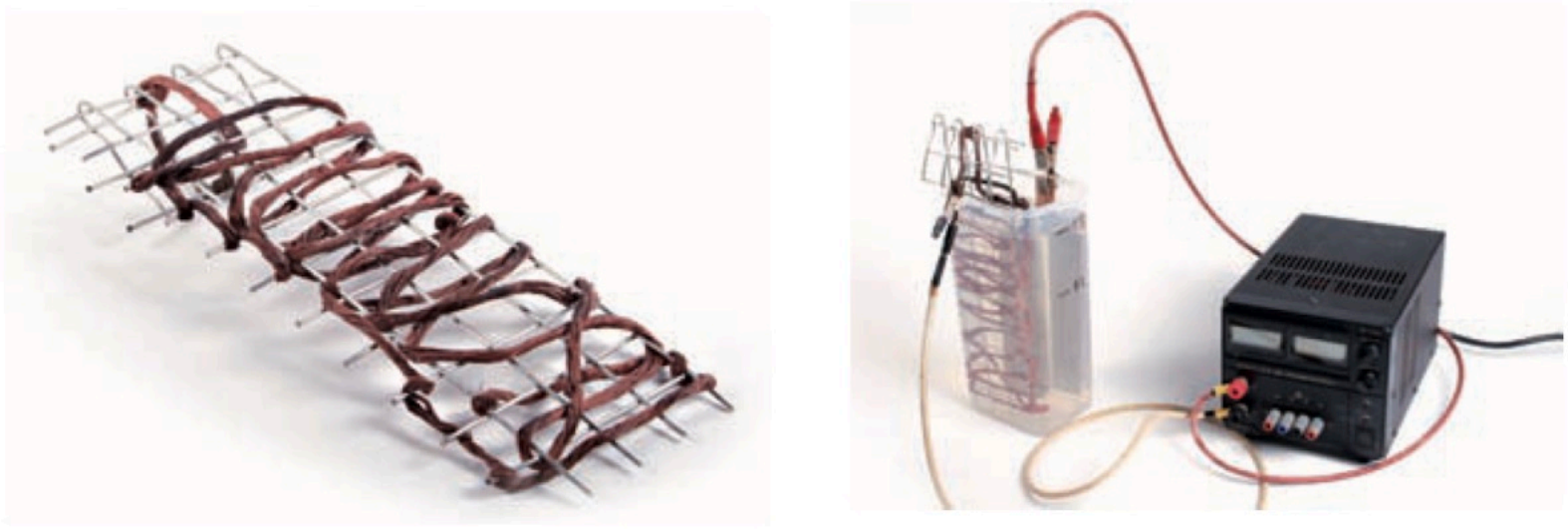
The aluminium plate is prepared as in the previous processes: a contact-strip of copper is attached –an aluminium contact-strip will be corroded (at least that is my experience), the plate is polished and degreased appropriately and, finally, a resist suitable for the drawing to be carried out is applied. Any of the resists suggested in this book can be used, although you should bear in mind that acrylic grounds could be less resistant in this process.

A standard vertical tank arrangement may be used: a cathode and a copper plate or a mesh connected to the negative pole (-) of the power supply; the plate to be etched connected to the anode (+).

The electrolytic concentration that Hernández-Chavarría uses is: "a quarter of a cup of table salt per litre of water". The voltage used was no more than 6 V and the amperage was between 1 and 5 A, with a bite time of between 15 and 40 minutes. He has also etched with a mobile phone charger of 0.3 A, even though it took two hours.

Etching on aluminium plates

All of my tests which I am going to describe have been carried out with a cathode made from recycled copper wire threading through a stainless steel mesh placed 6 cm from the aluminium plate anode.



On the left, anode with a copper wire threaded through a stainless steel mesh. On the right, electrolytic tank for sacrificial metal etching.

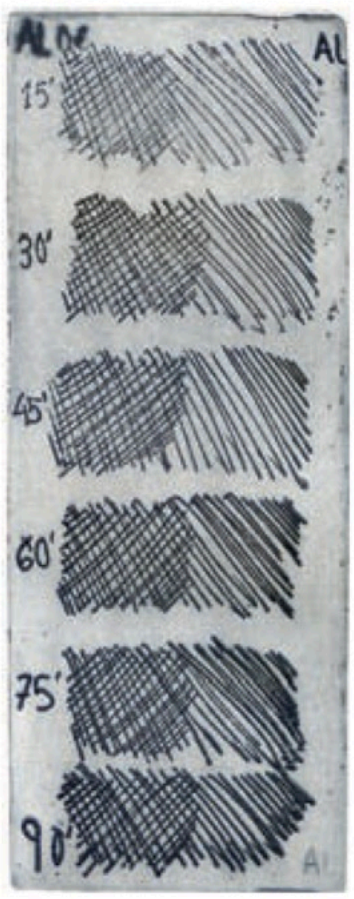
With a solution of 100 g of common salt added to a litre of water, a voltage of 2 V and a current of around 1.3 A, I did not get the results I had hoped for the line drawing, nor was electrotint generated in open bite. I concluded that the most important thing in etching aluminium with a common salt solution is that the amperage and the voltage must be kept low.

Etching lines

To etch lines of different intensities, use a 150 g of common salt/litre of water, a voltage of 1.25 V and an amperage of 0.5 to 1 A at intervals of 30 minutes.

Electrotint

To electrotint, use an electrolyte of 150 g of common salt/litre of water, a voltage of 1.25 V, and an amperage of 3 A at intervals of 30 minutes for a period of up to 150 minutes.



Test strips on aluminium plates. From left to right: etching lines, 150 g/l - 1.4 V - 3 A - six intervals of 15 mins; open bite electrotint, 150 g/l - 1.5 V - 3 A - three intervals of 15 mins and two of 30 mins; lift ground electrotint, 150 g/l - 1.5 V - 13 A - four intervals of 30 mins.

To electrotint using an ink resist, I used an electrolyte of common salt at 200 g/litre of water, a voltage of 1.5 V, and amperage of 3 A at intervals of 30 minutes. With this solution I tried to obtain shades using graphite ink diluted with *Leinnos Thinner 200*, applying the process used for copper, zinc and iron. It has possibilities as a resist, but I did not obtain a gradation of greys.

In general, the matrix created by electrotint does not have a regular surface and the dots are separated. Longer bites give an intense tone, although it is also irregular. It could be said that the plate is corroded in an irregular and dispersed way.

These tests using the *sacrificial metal* method to etch aluminium have been the most interesting to date. I do not find the process as easy to control as etching copper, zinc or iron by electrolysis.

After these experiences I decided to make contact with Professor Francisco Hernández-Chavarría via e-mail to discuss my conclusions. His quick response encouraged me to try electro-etching using sacrificial metal with plates of zinc and copper. At the same time Don Braisby contacted me from the UK to relate his experience of etching aluminium with common salt. This exchange across the Atlantic gave a new twist to electro-etching with common salt. In addition Bob Perkin who was reviewing this handbook knew about my experiences and has contributed to some general observations on the electro chemistry. The recent publication of a new article about electro-etching copper with common salt by Dwight Pogue, has aroused my interest once more.

At the time of writing this (October 2012), I think that it remains an open question as to whether or not this approach to etching aluminium is an addition to non toxic methods.There are several issues which must be resolved relating to the gases evolved and the by-products produced in the cell during the electrolysis.

Electro-etching with sodium chloride

The electrochemistry of common salt solutions with inert electrodes (ones which have no effect on the process) is well known. For all salt concentrations, hydrogen is produced at the cathode whereas at the anode, chlorine is produced at high concentrations; oxygen at low concentrations and a combination of the two at intermediate values. The use of an aluminium anode, the plate which is etched, may modify this picture insofar as it might reduce the production of chlorine and oxygen at the anode.

The bubbles of gas in the tank of sacrificial metal.

Both hydrogen and oxygen are insoluble in water and their presence can be seen as bubbles collecting on the respective electrodes. Chlorine is soluble in water and so may be contained within the electrolyte of the cell provided not too much is produced. Chlorine gas over a critical concentration is harmful but generally the human nose is sensitive to

concentrations below this level (not that this can be relied upon as a means of detection). Appropriate venting or trapping of these gases is required together with running conditions which minimise the evolution of chlorine gas. As an alternative, colleagues are looking at the concept of a "gell blanket" which traps the gases.

In the cell, aluminium hydroxide in the form of a gell is produced. This does not pose any particular safety or disposal problems but is more of a nuisance since it must be filtered out of the electrolyte at some point. The addition of vinegar prevents the formation of the aluminium hydroxide but may produce other by-products which can be corrosive.

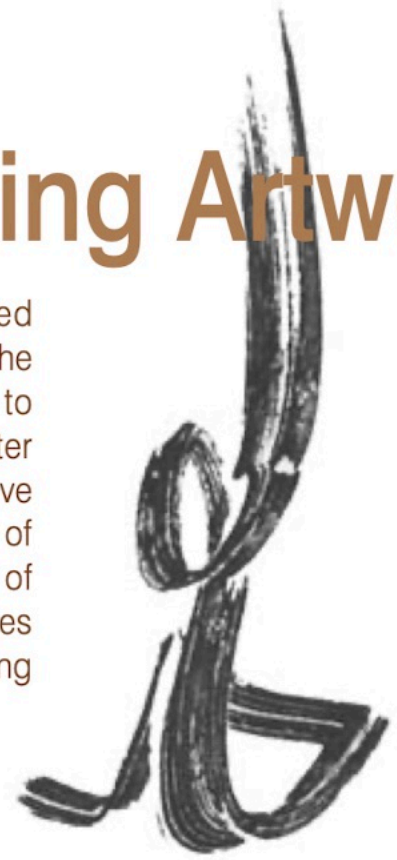
For the moment I think the technique is for the experienced and informed electro-etcher who wishes to explore, quantify and resolve the above issues and who is capable of assessing the safety aspects of their system*.

As I commented at the beginning of this section, these are techniques in progress and it is very likely, and desirable, that with time we can improve them in order to get images that faithfully express the intentions of the artist, while working safely.

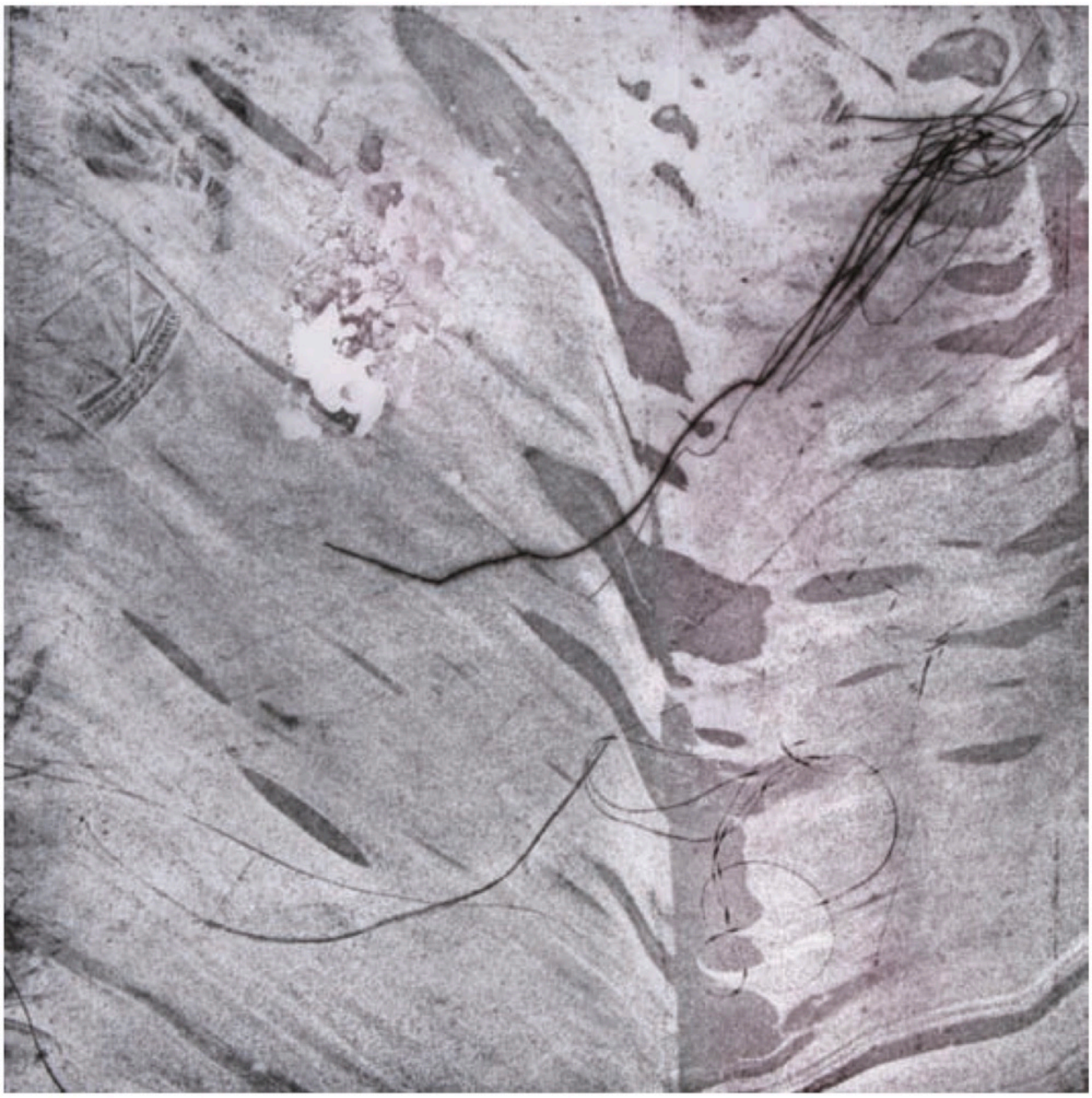
* More information about electro-etching may be found in the article "The basis of electro-etching - a simplified explanation" by A Crujera and B Perkin, published on the website www.en.crujera.com/publications/articles

Etching Artworks

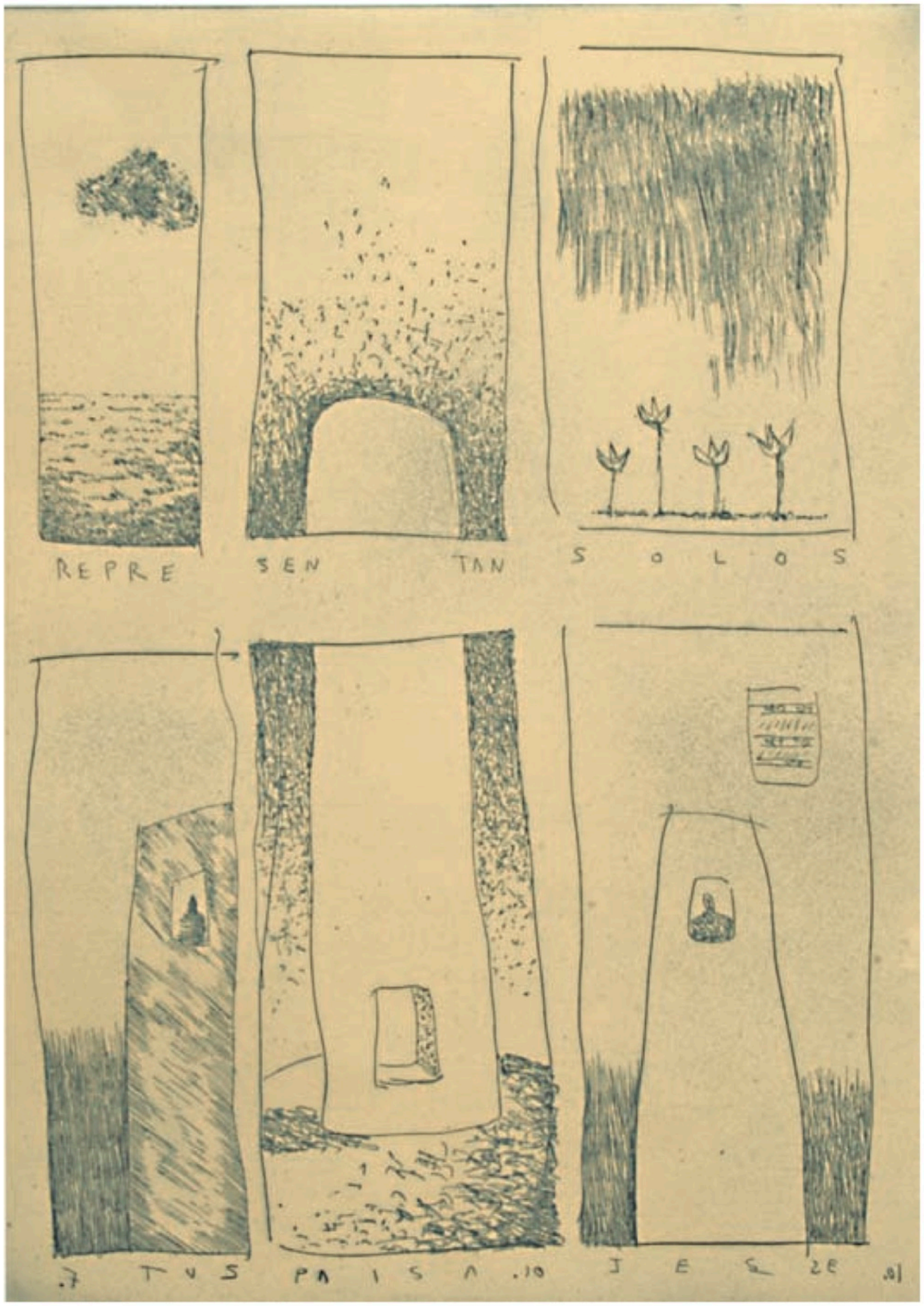
Any plate etched with the processes described throughout this handbook can be printed with the traditional techniques that have been used up to now for intaglio: dampening the paper with water beforehand, inking up the plate and wiping to leave ink only in the grooves or using rollers and inks of different viscosities and, finally, applying plenty of pressure with the etching press. The following pages present etchings by the author and other artists using the technique of electrolytic etching.



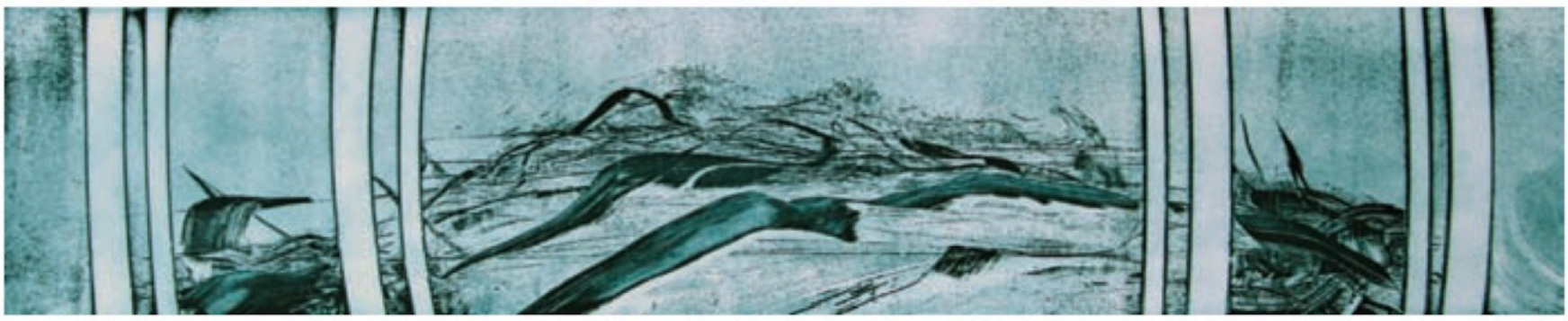
Rolf Håkansson. 2001
Electro-etching on copper plate
Electrotint with graphite ink
14.5 x 17 cm



Ana de la Puente. 2001
Electro-etching on copper plate
Electrotint and soft-ground with graphite ink and drypoint
39.5 x 39.5 cm



Miguel Panadero. 2001
Tus paisajes
Electro-etching on copper plate
Lines and electrotint with graphite ink
42 x 29.5 cm



Paqui Martín. 2001
Serie Recuerdos de una realidad anterior
Electro-etching on copper plate
Electrotint with graphite ink
10 x 49.5 cm

Pilar Rodiles. 2001
Serie Bidúm
Electro-etching on copper plate
Electrotint with graphite ink
21 x 15 cm

Félix Juan Bordes. 2005
Ovorriterne: desprendimiento nocturno
Electro-etching on copper plate
200 x 100 cm

Amparo Barreiro. 2006
Electro-etching on zinc plate
Hard ground and electrotint of open bite
20 x 12 cm

Ángel Cantero. 2006
Electro-etching on copper plate
Hard ground and electrotint of open bite
20 x 12 cm

Francisca Pagán. 2006
Electro-etching on copper plate
Lines and electrotint with graphite ink
20 x 12 cm

Manuel Delgado. 2007
Electro-etching on copper plate
Graphite ink with different techniques
24.5 x 15 cm

Carolina Parra. 2009
Venaooo
Lithography on galvanised iron plate
55 x 75 cm

Sara Cuesta. 2011
Semi-dry electro-etching on copper plate
20 x 12.5 cm

Luvier Casali. 2011
Pora diligencia
Electro-etching on copper plate
Soft-ground with graphite ink
25 x 16.5 cm

Odín Barrios. 2012
Pila de Bagdad
Electro-etching on iron plate
112 x 76 cm

Odín Barrios. 2012
La sombra de la tierra en la luna
Electro-etching on iron plate with screen
printing ink applied as a ground
112 x 76 cm

Liz Gartz. 2012
Paisaje
Electro-etching on copper plate
Lascaux resist and graphite ink electrotint
20 x 15 cm

Eunkang Koh. 2013
Careful approach
Electro-etching on copper plate
Lascaux resist and graphite ink electrotint
13 x 16.5 cm

Alfonso Crujera. 2001
Svenska Vår I
Electro-etching on copper plate
Soft-ground and electrotint with graphite ink
2 colours: intaglio and overprinted relief
21 x 8.8 cm

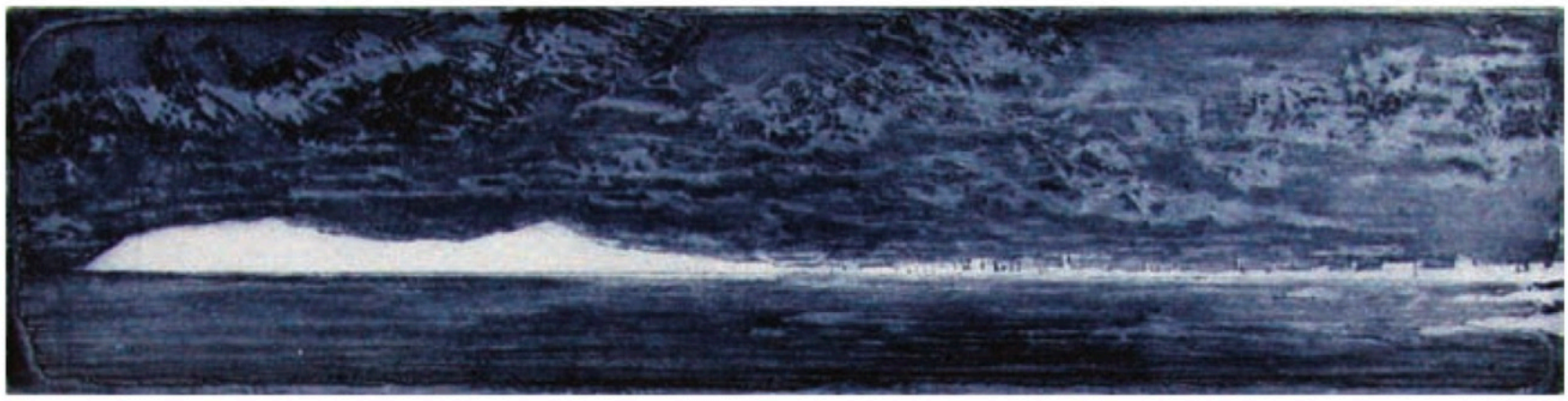
Alfonso Crujera. 2001
Svenska Vår II
Electro-etching on copper plate
Lines and electrotint with graphite ink
2 colours: intaglio and overprinted relief
24.6 x 18.8 cm

Alfonso Crujera. 2001
Svenska Vår III
Electro-etching on copper plate
Soft-ground and electrotint with graphite ink
2 colours: intaglio and overprinted relief
25 x 25 cm

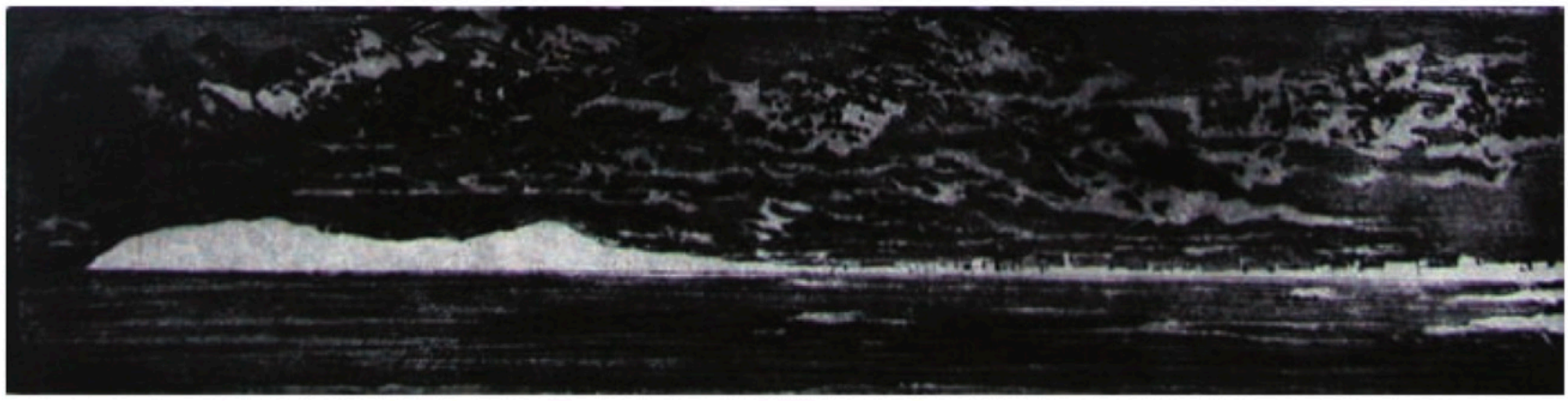
Alfonso Crujera. 2001
Svenska Vår IV
Electro-etching on copper plate
Soft-ground and electrotint with graphite ink
2 colours: intaglio and overprinted relief
25 x 25 cm

Alfonso Crujera. 2002
Punta del caletón I (Serie: LPGC)
Electro-etching on zinc plate
Hard ground and electrotint of open bite
6 x 14.5 cm

Alfonso Crujera. 2002
Punta del caletón III (Serie: LPGC)
Electro-etching on copper plate
Hard ground and electrotint of open bite
2 colours: intaglio and overprinted relief
6 x 14.5 cm



Alfonso Crujera. 2004
Punta del caletón V (Serie: LPGC)
Electro-etching on zinc plate
Galvanised electrotint
Intaglio printed in blue ink
10 x 40 cm



Alfonso Crujera. 2004
Punta del caletón V (Serie: LPGC)
Electro-etching on zinc plate
Galvanised electrotint
Intaglio printed in black ink
10 x 40 cm

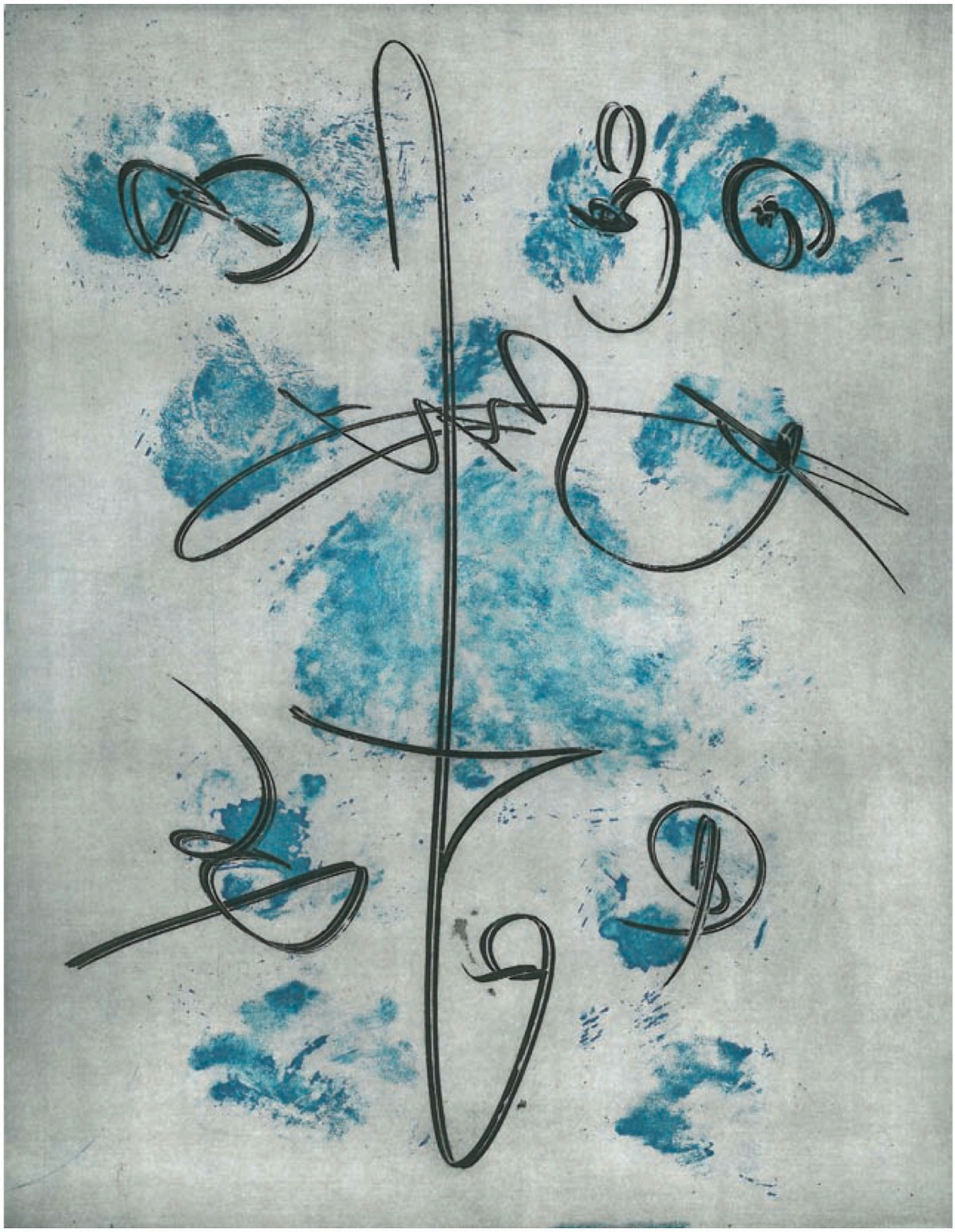
Alfonso Crujera. 2008
Charca residual
Galvanography copper plate
2 colours: brown intaglio and yellow overprinted relief
40 x 30 cm

Alfonso Crujera. 2008
Charca residual
Galvanography copper plate
2 colours: pink intaglio and green overprinted relief
40 x 30 cm

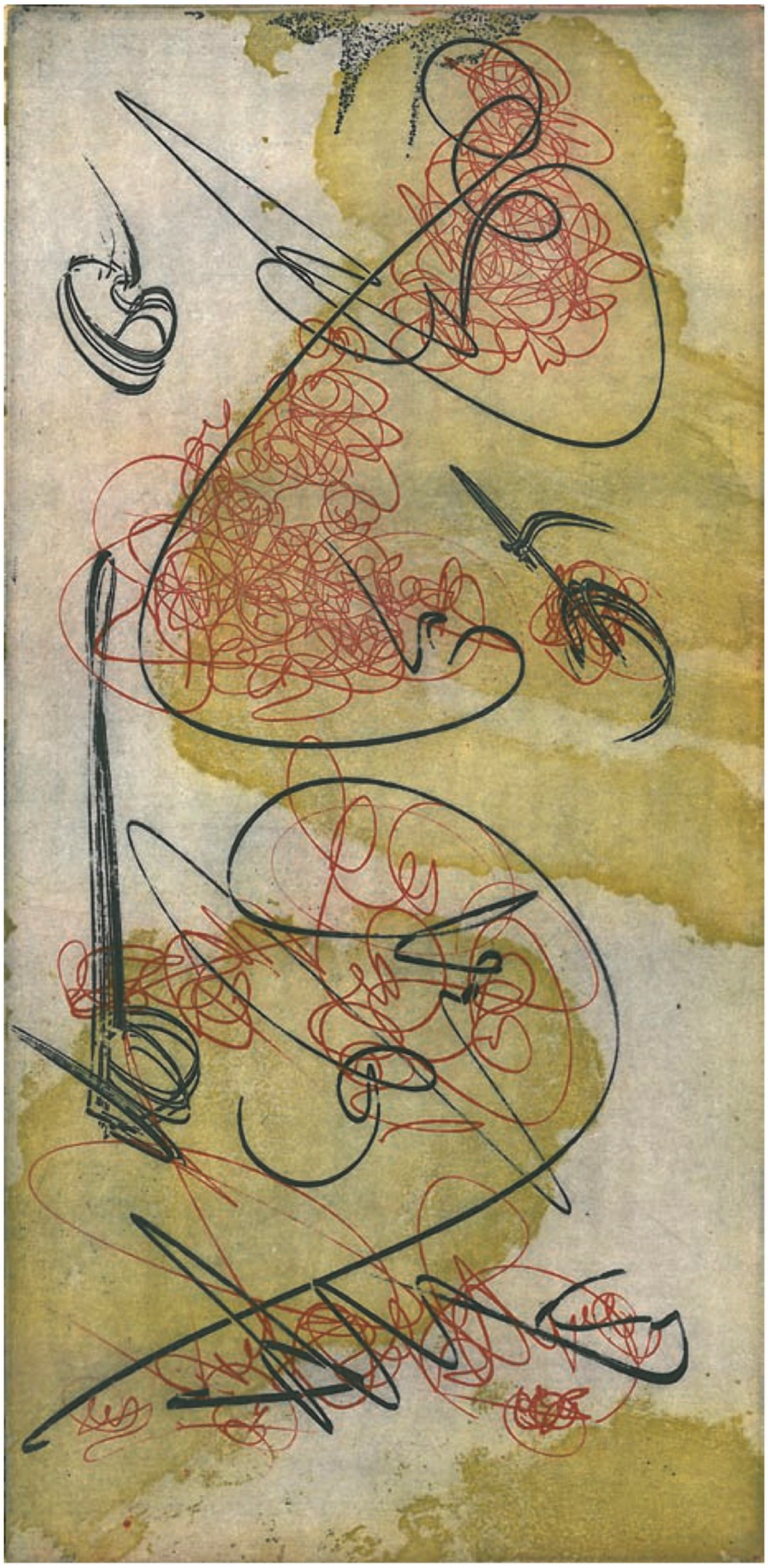
Alfonso Crujera. 2008
Barranco seco
Galvanography copper plate
2 colours: pink intaglio and blue overprinted relief
40 x 30 cm

Alfonso Crujera. 2008
Barranco seco
Galvanography copper plate
2 colours: brown intaglio and ochre overprinted relief
40 x 30 cm

Alfonso Crujera. 2009
Gpplh 5
Electro-etching on three zinc plates
Lines with hard resist and semi-dry process
3 colours intaglio printed
28 x 22 cm

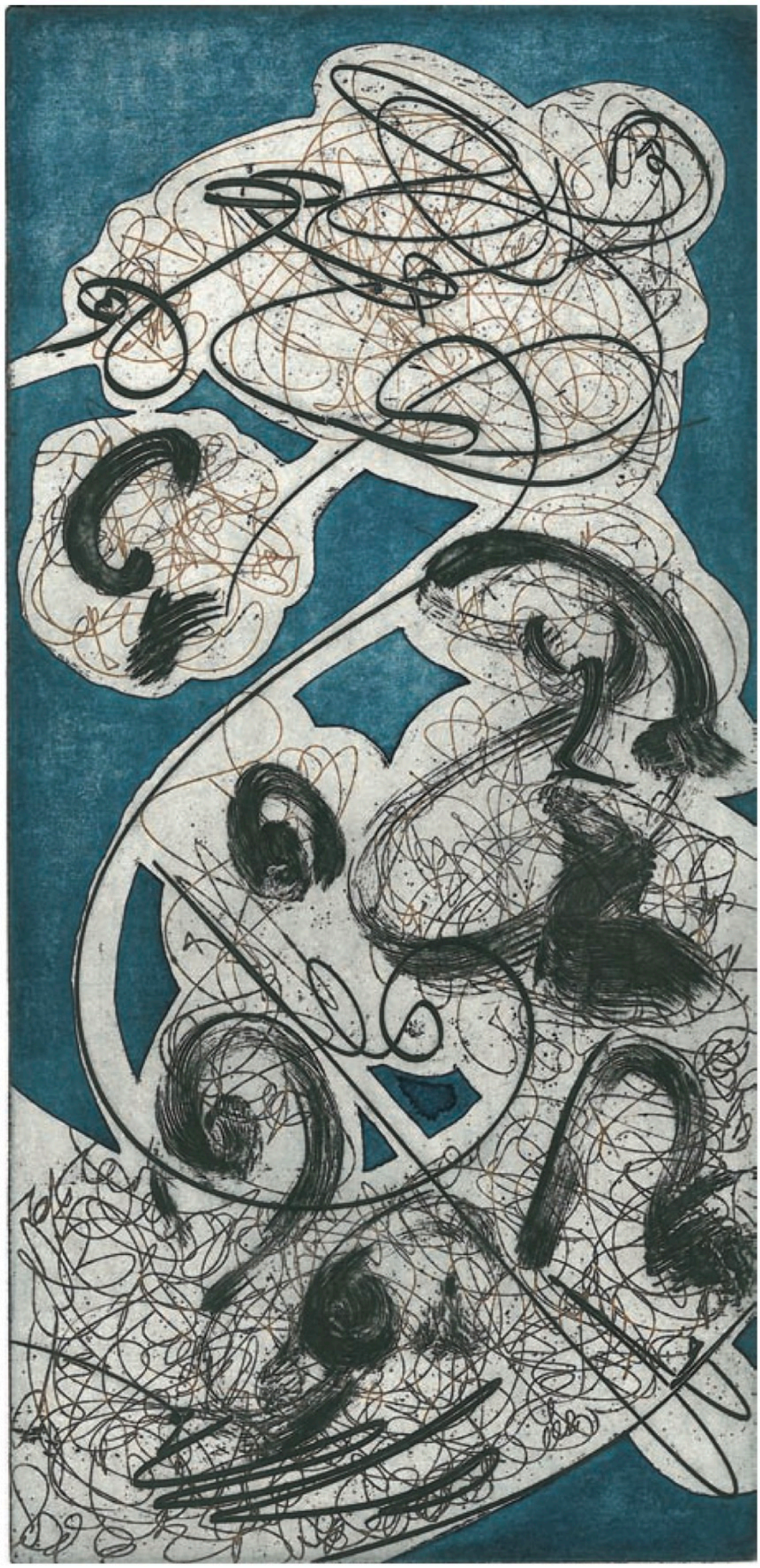


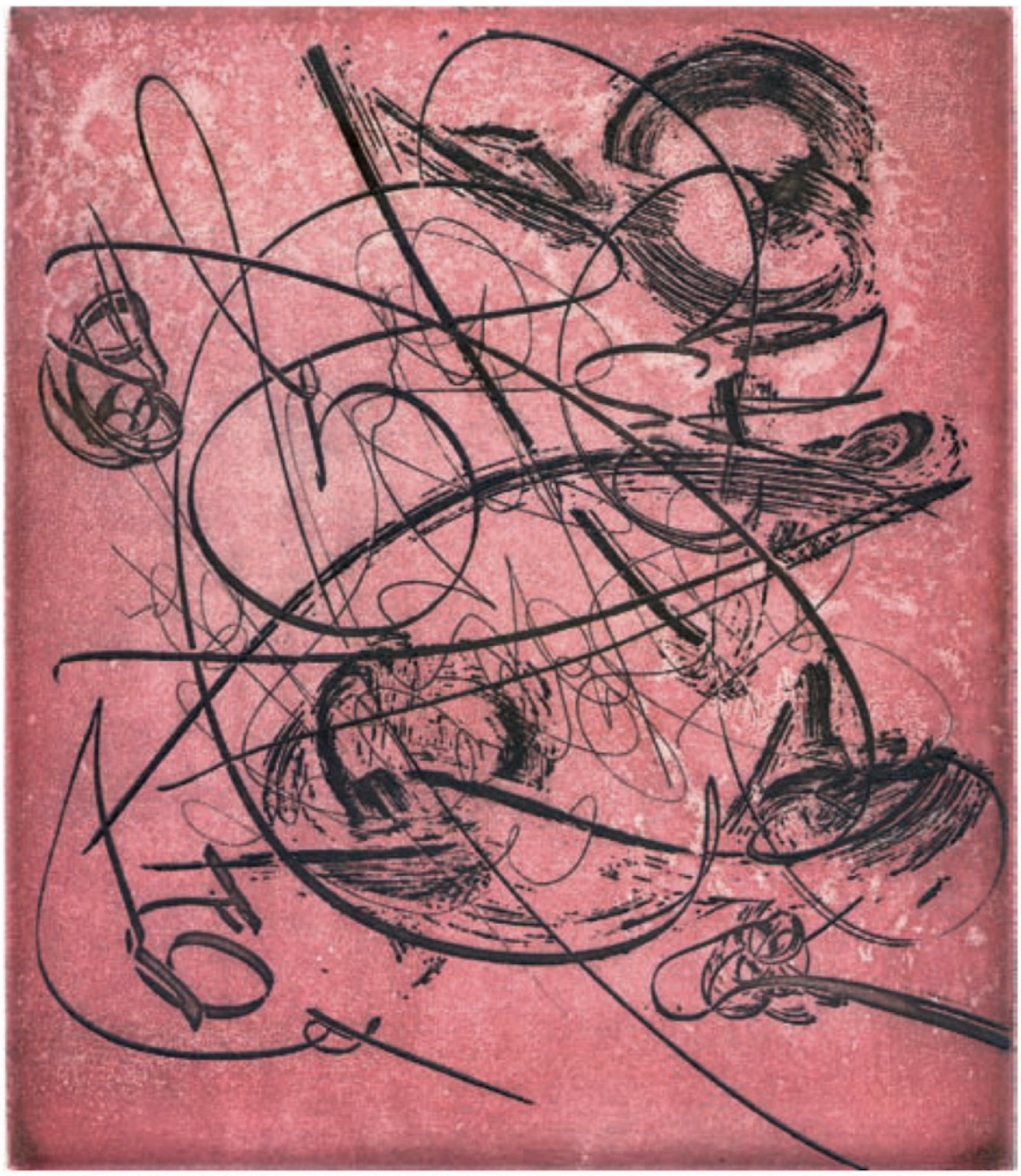
Alfonso Crujera. 2009
Gpplh 6
Electro-etching on two zinc plates
Lines and electrotint with graphite ink
2 colours intaglio printed
28 x 22 cm



Alfonso Crujera. 2009
Gpplh 7
Electro-etching on three copper plates
Lines and electrotint with graphite ink
3 colours intaglio printed
32 x 15.5 cm

Alfonso Crujera. 2009
Gpplh 8
Electro-etching on three zinc plates
Lines with graphite ink and open bite
electrotint. 3 colours intaglio printed
31 x 15 cm





Alfonso Crujera. 2009
Gpplh 3
Electro-etching on two copper plates
Lines and electrotint with graphite ink
2 colours intaglio printed
17.4 x 15 cm

Alfonso Crujera. 2009
Gpplh 9
Passive electro-etching on zinc plate
3 colours: first colour intaglio printed; other two colours applied with the roll-over technique
28 x 24.5 cm

Appendices

Precautions, advantages and disadvantages*

You have to devote time to electro-etching and make patience a virtue.

Alfonso Crujera

Precautions and safety measures

Throughout this handbook I have set out certain safety measures when required, and, although it may seem repetitive, for convenience and to emphasise the need for safe working, these are now brought together and summarised below:

- Avoid inhaling sulphate powders and avoid contact with the skin and eyes. Wear a dust mask and rubber gloves when handling the sulphates to prepare the electrolyte until they have been diluted in water.
- Always wear waterproof gloves when your hands have to come into contact with electrolytic solutions and wear safety glasses to protect your eyes from accidental splashing, otherwise handle the electrolyte with care. If your hands or other skin accidentally come into contact with the solution, wash thoroughly with water and, if you splash your eyes, rinse with plenty of water or saline solution and seek medical attention.
- If you have to store the electrolytes, do it in clearly labelled plastic containers with plastic caps, in a safe place out of the reach of children.
- Use the correct electrolyte for each plate.
- Before switching on the power supply check that all electrical connections have been made correctly.
- Remember that in electricity, generally the red terminal of a power supply is the positive pole (+) and the black terminal is the negative (-) (the colours of the terminals may differ from these).
- The terminals of the power supply have to be joined to the electrodes with screws or crocodile clips. The connections of the cathode's contact-strips must be made with the same metal,

* This chapter deals with established *active electro-etching* techniques for copper, zinc and iron plates. Some of the comments do not apply to passive electro-etching. In addition, more recent electro-etching developments for aluminium plates and general sacrificial metal processes are covered in the relevant chapter.

soldered to the plate and given two layers of resist to protect them from the electrolytic bath.

- When the plate is ready for etching, place it in the electrolytic bath, then switch on the power supply and monitor the voltage to ensure that it remains within the desired range.
- Etch with low voltage. If we use a voltage as high as 10 V to etch, the conductive solution generates hydrogen at the cathode and oxygen at the anode. It is possible for the hydrogen and oxygen gases to combine and explode on contact with a single spark, such as is caused by a switch. Avoid their formation by maintaining the voltage sufficiently low so as to prevent these gases being generated.
- A high concentration of the electrolytic solution together with high voltage –some 6 V– can generate the formation of oxygen at the anode, which, although not released as a gas, reacts with the metal, hindering the etching. Therefore, maintain a low voltage and use solutions of low concentration.
- Use a protective mask to avoid inhaling the graphite powder when doing galvanography.

Storage and treatment of residues

The electrolytic solutions that have carried electrical current do not produce residues, which avoids the nuisance of filtration. It has already been said that they are completely stable and balanced. They can be kept in plastic containers closed with plastic caps, clearly labelled and indicating the concentration and use.

If for some reason you want to recover the sulphate salts, evaporate the solution, using a flat tray covered with a pane of glass, on a sun roof. After a few days (depending on the sun) the sulphate will be in a solid state, in the form of blue crystals, that can be collected and stored for re-use; keep them in plastic containers, never metal. To speed up the evaporation process, you can heat the solutions in small quantities (3 to 5 litres) in an enamelled metal, glass or ceramic container until the volume of liquid is reduced by approximately 50%. Then transfer the solution to a tray and proceed as previously

explained. Bear in mind that the more concentrated solutions do not require such reduction in volume. Never continue to heat the solutions to the point that the liquid has evaporated completely.

In these days of changing environmental legislation, local disposal regulations and facilities should be checked out first.The advice given below is most relevant to the individual etcher and assumes small volumes of waste solutions diluted with water. Educational establishments will have their own protocol for treating waste solutions; often it will preclude any disposal of waste solutions into the sewage system.

The electrolytic solutions of zinc and ferrous sulphate that remain on the plates after having been etched can be washed off directly into a sink with running water without damaging the water system. Before washing copper plates etched with electrolysis, they must be submerged in the *rinsing tank*, a tank containing plenty of water and iron filings or iron wool. The copper ions that remain on the plates after they have been removed from the electrolytic bath quickly become disposable metal copper upon submerging the plates in the tank with the water and fine metallic iron particles. After some time the water in the tank will have turned yellow, and can be put down the drain after filtering with filter paper or a cloth strainer to remove the copper. The dirt and metal residue must be left to dry and deposited at the nearest local authority metallic waste collection point.

When you have used copper sulphate solutions, which generate metallic residues and become exhausted through etching, like those used for etching zinc plates by passive electro-etching, it is necessary to proceed in the following manner. If you have finished etching and the solution still retains its mordant quality, the residues generated in this etching process should be filtered with filter paper or cloth before storing in plastic containers, keeping it for later work until the mordant quality is exhausted. If the solution is completely exhausted, proceed as outlined in the paragraph on *Passive electro-etching*. The copper sulphate solution will have been transformed into a zinc sulphate solution, that should be exhausted fully by adding more zinc. Filter the residues and re-use the solution to etch zinc plates with electricity.

The dirt and metal residue should be left to dry and disposed of at a suitable collection site.

Advantages of electro-etching

The electro-etching alternative to acids is so interesting that perhaps it is worth being reminded again of its many advantages.

- You can etch plates of copper, zinc and iron using the same equipment and the same procedures. You will only have to change the electrolyte and the cathode grid.
- The electrolytic bite produces, well defined, sharp lines which are superior to conventional etching, thanks to the unique effect of the electrolysis, which is to bite perpendicular to the surface of the plate. The bite does not undermine the metal beneath the layer of resist, nor does it break the edges of these resists, with the result that the lines are very clean and shiny. Cross-hatched lines do not have the tendency to lose the definition of the individual lines and develop *crevés* due to the gradual fusion of these lines. An uneven surface is produced at the bottom of grooves which holds the ink very well, even in the widest lines.
- Etching with electricity does not generate toxic gases.
- When electro-etching is not taking place, the electrolytic solution in the tank is passive, not releasing any gases or undergoing any chemical reactions.
- The electrolytic bite does not produce gas bubbles that impede the etching; consequently, it is not necessary to keep watch in order to remove these bubbles as is necessary with acids. While the etching in a tank progresses we can be working on other plates.
- The electrolytic bite does not generate metallic residue that accumulates in the grooves and stops the etching. For this reason, we do not have to filter the solutions if we wish to store them.
- The electrolytic solutions do not become exhausted with successive bites, and, therefore, it is easier to calculate bite times. Neither do we have to continually replace the mordant, with the consequent financial saving. This is in contrast with etching with acid, where once the acid solution has been used, it loses its strength, and

becomes weaker with each subsequent use, until it becomes exhausted. Electrolysis eliminates this problem completely: I am still using the same electrolytic solutions that I started working with in 2001.

- The depth of the lines created: with the same value of electrolyte concentration and the same distance between the electrodes, in a given time and with a given voltage, the lines will have the same characteristics.
- On the surface of the metal that has not been protected with stop-out, electro-etching produces a uniform porous structure that retains ink, we have named this effect *electrotint*. It is similar to traditional *aquatint*, but does not use sprays and the subsequent melted asphalt or resin dust, both considered rather toxic.
- In the etching workshop you can save the expensive investment in a fume extractor hood required to protect etchers from the noxious fumes generated in traditional etching with acids.
- In contrast to using an acid bath, from which the plates have to be taken out as soon as etching is finished, in an electrolytic bath the etching halts when we turn off the current from the power supply. The plates can remain submerged for short periods of time with the electrolytic unit disconnected, as the corrosion in the grooves will not continue. If left for longer periods the electrolyte can penetrate between the contact-strip and the plate, causing the plate to sink to the bottom of the tank or lifting the resist.

Economic advantages

Finally, we must also bear in mind that once the electrolytic unit has been acquired, it is a very cheap system for etching. There are two reasons for this.

Firstly, due to the stability of the mordants –which never lose their corrosive capacity– the only expenditure on sulphates is in preparing the electrolyte to fill the tank for the first time. The electrolyte can be stored for a long time if, after use, we store it in containers or cover the tanks. It will only be necessary to replace the electrolyte lost due to decanting or evaporation.

Secondly, the electrical consumption of the electro-etching unit is lower than a 60 W lamp. You can calculate the power consumption using power (Watts) equals volts x amps. For example, an electro-etching of 0.5 V x 1.5 A = 0.75 W; another one of 1.0 V x 2.0 A = 2.0 W. It is also obvious that the consumption is much less than the fume extractor hood essential in any workshop where etching with acids takes place. And, of course, the use of an air dryer (1600 W) and a hot plate (2500 W) used to heat the plates and dry the inks for conventional etching, consumes additional electricity.

In addition, it also offers us the opportunity to recycle materials: the printed plates can be used at the anode to *galvanise electrotint*, *micro dots* or *galvanography*; and recycling the copper sulphate electrolyte which has turned into an electrolyte of zinc sulphate in the process of passive electrolytic etching, for use in *active electro-etching* zinc plates.

Disadvantages of electro-etching

The alternative to acids that we have found in electrolytic etching has offered us a series of advantages which have been outlined in the previous section. But there are also several disadvantages presented by this process and this method of etching, which I want to list here.

- The necessity of protecting yourself with rubber gloves and a dust mask so as not to inhale the sulphate before it has been dissolved and to avoid it coming into contact with the skin and eyes once it has been diluted.
- The *edge effect*, the tendency to bite isolated lines more intensely than those that are closer together or cross-hatched. The technique also bites the areas at the edge of the plate harder than in the centre. Also, the electrolytic action acts with greater intensity at the edges of wide lines and at the edges of the stop-out on large areas of open bite. However, using a cathode grill in the electrolytic unit, in general, counteracts many of these drawbacks.
- The fact that it does not use resin dust or asphalt dust limits the possibility of achieving a flat, even tone of different intensities as with traditional aquatint, used for several centuries.

- Using electricity to etch may be a disadvantage for some etchers, as they do not want to use this energy source which may seem dangerous. However, the range of voltages and currents described represent a low electrical hazard which is further minimised by observing the general precaution of keeping well clear of the electrical components when the electro-etching unit is operated.

There have been attempts to remedy a number of these drawbacks but there is still some way to go. However, with practice, we will certainly find a way to improve and avoid them.

Data charts for electrolytic etching

I am confident that any etcher will be able to experiment and obtain interesting images with the different methods outlined in this book. In order to facilitate this process, I have included the following charts summarising various useful data extracted from the main text. The electrolyte concentration gives the typical range; the electrolyte used can be found in the appropriate section. The variation in bite times for a given entry applies to all the electrolyte concentrations and gives the useful maximum and minimum bite times: the depth of bite and intensity of the etch increase with bite time, see, for example, the test strips on page 58.

ELECTRO-ETCHING DATA CHART: COPPER PLATES

TECHNIQUE	ELECTROLYTE CONCENTRATION[1]	VOLTAGE[2]	BITE TIMES[3]
Lines on hard ground	160 - 250	0.5	15 - 120
Intaglio ink and graphite ink hard ground	200 - 250	0.5	15 - 60
Open bite electrotint	160 - 200	0.5	15 - 120
Electrotint with graphite ink	200 - 250	0.5	60
Soft-ground 150	160 - 250	0.5 - 1	60
Soft-ground with graphite ink	200 - 250	0.5	60
Deep bite relief	160 - 200	0.5 - 1	60 upwards
Semi-dry electro-etching	250	1 - 1.5	60 - 120
Galvanised relief lines	200 - 250	0.5 - 1	30 - 180
Galvanised electrotint	160 - 200	0.5 - 1	30 - 120
Galvanising for Mezzotint	200 - 250	0.5 - 1	4 - 8 hours
Galvanising for litography	200 - 250	0.5 - 1	4 - 8 hours
Galvanografy	200 - 250	0.5 - 1	20 - 24 hours

Notes for both data charts

1. Grams of copper or zinc sulphate/litre of distilled water.
2. In volts.
3. In minutes.

* As the mordant becomes exhausted, the time indicated is approximate.

ELECTRO-ETCHING DATA CHART: ZINC PLATES

TECHNIQUE		ELECTROLYTE CONCENTRATION[1]	VOLTAGE[2]	BITE TIMES[3]
Lines on hard ground		160 - 500	0.5	15 - 120
Intaglio ink and graphite ink hard ground		200 - 300	0.5	15 - 60
Open bite electrotint		160 - 300	0.5	15 - 120
		300	1	15 - 120
		500	0.5	15 - 120
Electrotint with graphite ink		300	0.5	60
Soft-ground 150		225 - 300	1	60 - 120
Soft-ground with graphite ink		250 - 300	1	60
Deep bite relief		250 - 300	0.5 - 1	60 upwards
Semi-dry electro-etching		250	1	60 - 120
Galvanised relief lines		300	0.5 - 1	30 - 60 - 90
Galvanised electrotint		300 - 500	0.5 - 1	30 - 60
Galvanografy		300	0.5 - 1	20 - 24 hours
Passive electrolytic etching	Etched lines	160	Electricity self-generating	10 - 20*
	Soft-ground	250	Electricity self-generating	10 - 20*
	Deep bite	250	Electricity self-generating	15 - 120*

ELECTRO-ETCHING DATA CHART: IRON PLATES

TECHNIQUE	ELECTROLYTE CONCENTRATION[1]	VOLTAGE[2]	BITE TIMES[3]
Lines on hard ground	200 - 250	0.5 - 1	30 - 130
Intaglio ink and graphite ink hard ground	200 - 250	0.5 - 1	30 - 90
Open bite electrotint	200 - 250	0.5 - 1	30 - 150
Electrotint with graphite ink	200 - 250	0.5	30 - 90
Soft-ground with graphite ink	200 - 250	0.5	30 - 90
Deep bite relief	200 - 250	0.5 - 1	60 upwards

Notes for both data charts

1. Grams of copper, zinc or ferrous sulphate/litre of distilled water.
2. In volts.
3. In minutes.

COMPARATIVE DATA CHART OF ELECTRO-ETCHING ON **ZINC** PLATES **WITH** AND **WITHOUT POWER SUPPLY**

Process	Electro-etching with electricity	Electro-etching with electricity	Passive electro-etching	Passive electro-etching with saline reservoir
Electrolyte	Zinc sulphate	Zinc sulphate	Copper sulphate	Copper sulphate
Concentration	300 g/litre	300 g/litre	250 g/litre (it becomes exhausted)	250 g/litre (it becomes exhausted)
Voltage	0.5 V	1 V	-	-
Bite times[3] for line	15	< 15	2	2
	45	30	3	3
	75	60	5 (line widens)	5
	120	75	10 (line widens)	10
	-	120	25 (line widens)	20
Time[3] of open bite for deep relief	120	75	10	10
	-	120	30	20
	-	-	40	30
	-	-	100	80
	-	-	140	120
1 mm depth			180	160
Micro dots	45	15	60	30
	75	45	-	-
	120	75	-	-

COMPARATIVE DATA CHART OF **VARNISHES** AND **RESISTS**

TRADITIONAL		ALTERNATIVE	
	Dangers		Safety measures
Liquid, hard, stop-out, and soft grounds made by turpentine, wax, asphaltum, grease, methanol.	The fumes given off by these grounds, above all when heated, can cause headaches and depression of the central nervous system. Asphalt in powdered form is a carcinogen and can cause headaches, irritation of the eyes, skin and nasal mucous membrane, in addition to dermatitis.	Acrylic floor wax hard ground for line drawings. It is a ground made with polymers and acrylic wax that polymerises when dry.	It is a domestic cleaning product that does not give off fumes, use latex gloves. Avoid splashing the eyes.
		Acrylic liquid hard resist and stop-out resist (*Lascaux*) for line drawings. They are made with monomers that polymerise when dry.	It is a product that does not give off fumes. Avoid splashing the eyes.
		Intaglio ink and graphite intaglio ink hard and soft grounds made with pigment and linseed oil.	The oil base and pigments do not produce toxic fumes. You can work with latex gloves to avoid staining your hands.

COMPARATIVE DATA CHART

TRADITIONAL **AQUATINT**		ALTERNATIVE **ELECTROTINT**	
	Dangers		Safety measures
Rosin and asphaltum powders volatilized and melted.	Rosin powder is toxic when inhaled and can cause allergies and irritation of the eyes. When melted, the fumes are toxic, causing respiratory problems and pulmonary fibrosis.	Electrolytic etching generates micro dots on unprotected metal.	Handle sulphates in solid state with rubber gloves and a dust mask. Use rubber gloves when handling solutions and avoid splashing, or protect your eyes with suitable glasses.
		Graphite ink mixed with *Leinos Thinner* oil	
		Sem-dry electro-etching.	
		Galvanised electrotint	
		Saline sulphate etch generates micro dots on unprotected metal.	

COMPARATIVE DATA CHART OF **MORDANTS**

TRADITIONAL		ALTERNATIVE	
	Dangers		Safety measures
Copper plates Nitric acid. Hydrochloric acid (mordant Dutch). Ferric chloride.	Once the bottles are open the solutions give off toxic fumes. During the etching process they also generate toxic fumes of nitrogen dioxide and hydrogen chloride. These gases irritate the eyes, affect the lungs, the nasal mucous membrane and the skin. They cause coughing, inflammation of the nose, trachea and larynx.	Copper plates Electro-etching Semi-dry electro-etching Edinburgh etch	Sulphates in solid state (base of these mordants) must be handled with rubber gloves and dust mask. They do not give off fumes when diluted. Electrolytic and saline solutions must not come into contact with the skin or the eyes. Wear rubber gloves to handle the solutions and avoid splashing, or protect your eyes with suitable glasses. Toxic fumes are not produced during the etching process.
Zinc plates Nitric acid. Ferric chloride.		Zinc plates Electro-etching. Semi-dry electro-etching. Passive electro-etching*. Bordeaux etch*. Saline sulphate etch*.	
Iron plates Nitric acid.		Iron plates Electro-etching. Semi-dry electro-etching. Saline sulphate etch*.	
Aluminium plates There are no traditional mordants.		Aluminium plates Sacrificial metal electro-etching*. Saline sulphate etch*.	*Hydrogen gas is produced during the etching process, and while not toxic, it requires etchers to work outdoors or use a fume extractor hood.

COMPARATIVE DATA CHART OF **DIFFERENT MORDANTS**

	Nitric acid	Mordant Dutch (Hydrochloric acid)	Saline sulphate (with or without sodium chloride)	Electro-etching on copper (copper sulphate)	Electro-etching on zinc (zinc sulphate)	Electro-etching on iron (ferrous sulphate)	Passive electro-etching on zinc (copper sulphate)
Solution free from fumes	No	No	Yes	Yes	Yes	Yes	Yes
Etching process free from fumes	No	No	No	Yes	Yes	Yes	No
Exhaustion of the solution	Yes	Yes	Yes	No	No	No	Yes
Generation of precipitates that halt the etch	Yes	Yes	Yes	No	No	No	Yes
Solutions free from disposable residues	No	No	No[1]	No[2]	Yes	Yes	No[3]
Predictible etch time	No	No	No	Yes	Yes	Yes	No
Tonal effects without rosin or asphaltum	Very little	Very little	Yes	Yes	Yes	Yes	Little
Cracking of resist	Yes	Yes	No[4]	No	No	No	No

Notes

1. Counteract with sodium carbonate.
2. Counteract with iron filings.
3. See on page 170 *Storage and treatement of residues*.
4. Up to a certain amount of time.

COMPARATIVE DATA CHART OF **SOLVENTS**

TRADITIONAL		ALTERNATIVE	
	Dangers		Safety measures
Cleaning varnishes, grounds, inked plates and tools Turpentine, white spirit, petroleum.	The fumes given off by these solvents are strong odours and toxic, they can cause headaches and depression of the central nervous system, irritation of the eyes, damage of skin and nasal mucous membrane. Narcotic effects by inhalation. Prolonged exposure can cause chronic bronchitis and pulmonary edema.	Cleaning of acrylic varnish of wax Sodium carbonate and water. Cleaning of *Lascaux* resists *Lascaux* remover, *Mystrol*, alcohol. Cleaning of intaglio ink and graphite ink hard and soft grounds Vegetable cleaning agent (VCA), *Novasol-N.* Cleaning of inked plates and tools Vegetable cooking oil cheap, sunflower oil, vegetable cleaning agent (VCA), *Novasol-N.*	Wear rubber gloves.
Cleaning melted rosin from the plate Universal W/B solvent, naphtha.			

Glossary*

*Sources of information: The free dictionary: www.thefreedictionary.com / Wikipedia, the free encyclopedia: en.wikipedia.org/wiki/main_page / Enciclopedia Salvat-El País / Foro de arte de Barcelona / Diccionario del dibujo y la estampa de la Calcografía Nacional (Madrid 1996) / Diccionario de la lengua española de la Real Academia Española (DRAE).

Glossary and documentary sources

NAME *SYNONYMOUS*	FORMULA *SYMBOL*	DESCRIPTION
Acacia gum *Gum Arabic / Gum syrup*		A natural ancient gum made of hardened sap taken from acacia wild trees from the Sahel. Used primarily as a stabilizer for food. Widely used by cosmetics and textile industry. It is a very important ingredient in lithography, as binder for watercolour painting and used as a component of lift-ground.
Acetic acid *Vinegar*	CH_3CO2H	Acid found in vinegar with sour flavour and smell. Too weak to bite metal, it is usually used mixed with table salt to degrease plates and lines before submerging them in the mordant bath. It is also used in the electrolytic process of sacrificial metal to counteract the production of hydroxides.
Acetone *Propanone*	$(CH_3)_2CO$	Colourless liquid with characteristic odour and taste. It evaporates easily and is flammable. It can be found in natural and synthetic forms. It is used in the manufacture of plastics, fibres, medications and other chemical products, as a solvent for other chemical substances. It is used in the workshop to lift very resistant layers.
Alternating current	*AC*	Electrical current in which the magnitude and direction vary cyclically. It is the form of electricity normally used in the home.
Ammonia	NH_3	Ammonia is a colourless gas with a very strong odour. It dissolves easily in water and evaporates quickly. It is sold in liquid form. It biodegrades easily in low concentrations. It is advisable to avoid inhalation. Dissolved in water it is used in the workshop to lift very resistant layers of acrylic resist.
Ammonium ferrous sulphate	$NH_4Fe(SO_4)_2$	A chemical compound derived from iron which forms a dust like a pale green turquoise sand. It is used in electro-etching and galvanisation of iron.
Amperage *Amps / Current*		The amount of amperes flowing in the cell or loosely speaking the electrical current.

Ampere *Amp*	*A*	The ampere is the basic unit of electrical current.
Anion		Ion with negative electric charge, (excess of electrons). Salts are typically formed by cations and anions.
Anode *Positive pole*	*(+)*	Electrode connected to the positive terminal of a DC power supply.
Anodic etching *Electrolytic etching / Electro-etching*		Etching by electrolysis, also called this because the plate to be etched is connected to the anode. See: Electro-etching.
Aquatint		Etching process through which varying tonal areas can be achieved; from the lightest grey to the darkest black. The technique consists of sprinkling fine particles of rosin or asphaltum on the plate and melting this layer of dust, to form a matrix of small dots around which the mordant will penetrate. The plate is usually bitten by acids. The “tooth” formed holds the ink to enable dark areas to be printed.
Asphaltum *Bitumen*		A mineral which in its natural state is formed from a complex mixture of solid hydrocarbons (carbon, tar, etc). Pulverised particles of the mineral are used for the aquatint technique. It has a melting point of approximately 93ºC. When melted it gives off –toxic fumes if overheated. It is a component which can be found in the majority of traditional etching grounds.
Bas relief		Originally a sculptural term, a relief in which the raised elements are only slightly above the surrounding overall flat background
Bite		Corrosive action carried out by an acid, saline sulphate or electrolysis on the drawn lines and exposed areas of bare metal of the plate.
Bitumen *Asphaltum*		See: Asphaltum
Bordeaux etch		Solution of copper sulphate which is used to bite zinc plates.
Calcium carbonate *Whiting*	$CaCO_3$	Light and porous material mainly composed of dolomitic chalk. Used in paint manufacture, particularly tempera (a mix of gypsum and calcium carbonate). It is used mixed with vinegar to degrease plates.

Cathode *Negative pole*		Electrode connected to the negative terminal of a DC power supply.
Cathode grid *Cathode mesh / Cathode plate*		The plate or the grid connected to the negative pole, which generally remains submerged in the electrolytic tank.
Cathode mesh *Cathode grid / Cathode plate*		See: Cathode grid
Cathode plate *Cathode grid / Cathode mesh*		See: Cathode grid
Cation		Ion with positive electric charge (lack of electrons). Salts are typically formed by cations and anions.
Citric acid	$C_2H_4O_2$	Organic acid present in the majority of fruits, especially citrus fruits like lemons and oranges. Natural preservative and antioxidant used industrially as an additive in the canning of foods. Used mixed with bicarbonate of soda and water to degrease the plates; also mixed with water for cleaning the copper oxide which may form on the copper cathode when it is not immersed in the electrolyte.
Collagraphy		A print made from a plate usually made of cardboard or masonite where an image is built up with materials such as paper, fabric or leafs.
Common salt *Sodium chloride / Table salt*	NaCl	It has a crystaline structure. The salt most responsible for the salinity of the ocean and of the extracellular fluid of many multicellular organisms. Ionic compound formed by a Na+ cation (sodium ion) and an anion ion Cl- (chloride ion). Mixed with acetic acid it is used to degrease the plates. It is used in the electrolyte for sacrificial metal etching, and to make mordants with a copper sulphate base more corrosive –essential for biting aluminium plates.
Concentration		Quantity of salts or acids contained in a solution per litre of water, expressed as grammes of salt per litre of water g/l.
Contact-strip		Long, narrow piece of metal used to connect the plates to the electrodes.
Copper sulphate	$CuSO_4$	A compound derived from copper which forms blue crystals that are soluble in water and methanol. In addition to using

NAME *SYNONYMOUS*	FORMULA *SYMBOL*	DESCRIPTION
Cupric sulphate		it for electro-etching copper plates and as non-toxic saline sulphate mordant. It has numerous applications, the most important being fertilizers, pesticides, textile mordants, pigments, electric batteries, galvanised coatings.
Crevé *Flat biting*		A bite on the plate which does not retain ink, generally created accidentally by cross-hatched lines merging through the action of the acid or alternatively, because the surface bitten by the acid is too large.
Current *Amperage / Amps*		See: Amperage
Deep bite *Dry relief printing / Embossing*		Extended attack of a mordant on a plate to achieve a deep corrosion for the purpose of inking the grooves and the surface of the plate with a roller, or for printing the relief of the plate without ink, for embossing and dry relief printing.
Degreasing		Removal of grease from plate prior to etching. An essential operation for etching on metal plates with any corrosive mordant solution. A large variety of products can be used. Soap, alcohol, vinegar and salt, calcium carbonate, citric acid.
Deionised water	H_2O	Water from which ions (electrical charges) have been removed. It can contain small quantities of non-ionic purities like organic compounds. It is similar to distilled water in that it is used for scientific experiments. Deionised water can change its pH once stored as the absorption of atmospheric CO_2 increases its acidity, but this can be removed by boiling. Deionised water is quite aggressive on metals, even stainless steel. For this reason, plastic or glass should be used for its storage and handling.
Direct current	*DC*	Electric current flowing in one direction, in contrast to alternating current. Produced by sources such as batteries. Its discovery gained recognition with the invention of the first voltaic battery by Italian scientist, Alessandro Volta.
Direct current power supply *DC power supply / Power supply*		Device which converts the alternating current from the mains supply to a direct, continuous current. It may have controls and digital displays for the current, amperage and voltage.

Dissolution *Solution*		Smooth mixture of two or more components that are found in a particular proportion.
Distilled water	H_2O	Water from which practically all impurities and ions (electrical charges) have been removed by distillation. Due to its increased purity, some properties of this water are significantly different from the water used daily. The conductivity of distilled water is noticeably lower than tap water as it lacks the ions which contribute to conductivity. It is not as good a conductor of electricity as tap water.
Dry relief printing *Deep bite / Embossing*		Printing on damp paper of high grammage without inking a relief matrix.
Drypoint		It is a direct process to draw on plates of metal (or plastic) with sharps needles, without the action of mordants such as: an acid, a salt or an electrolyte.
Dutch mordant		Solution of hydrochloric acid, potassium chlorate, and water. Used for etching copper plates.
Edinburgh etch		A saturated solution of ferric chloride and citric acid used to bite copper plates.
Electro-deposition *Electro-plating*		The process of applying a metallic layer on another material by electrolytic methods. Steel plated, chrome plated, galvanising.
Electro-etching *Anodic etching / Electrolytic etching*		Process of intaglio etching which uses electrolysis –with or without an electrical power supply– instead of acids to corrode the image drawn on a metal plate connected to the anode in an electrolytic tank.
Electrode		A conductor connected to the positive or negative terminal of a DC power supply.
Electroforming *Electro-plating*		Technique consisting of the coating of objects or mandrels with a fine metallic layer through electrolytic processes. It is carried out for protective or decorative purposes.
Electrography		A generic term for various technical procedures based on the reproduction of images in copying machines by electrostatic printing. One of these procedures is xerography, the product of which is known as the photocopy.

NAME *SYNONYMOUS*	FORMULA *SYMBOL*	DESCRIPTION
Electrolysis		Chemical change caused by passing electricity through salts dissolved in a suitable solvent –electrolytes. Results in chemical reactions at the electrodes and separation of materials.
Electrolyte *Electrolytic solution*		A solution that conducts electricity due to the presence of dissolved salts in the water which create ions. These solutions are called electrolytic solutions. Used for etching with electrolysis.
Electrolytic cell *Electrolytic unit*		Unit formed by a tank of electrolytic solution, two electrodes, the cathode plate (or grid), and a source of continuous current. The plate to be etched is placed into the tank and connected to the anode electrode.
Electrolytic etching *Anodic etching / Electro-etching*		See: Anodic etching / Electro-etching
Electrolytic solution *Electrolyte*		See: Electrolyte
Electrolytic tank		Plastic tank or tray, which contains the electrolyte, the electrodes, cathode and plate to be etched which are held vertically (tank) or horizontally (tray) where the plates are etched.
Electrolytic unit *Electrolytic cell*		See: Electrolytic cell
Electroplating *Galvanisation / Galvanoplasty / Electroforming*		Based on the same electrolytic principles, electroplating consists of two different techniques: Galvanoplasty consists of producing metallic copies of models of different materials. Electroforming consists of coating objects with a metal coating.
Electrotint *Microtint / Galva-tone*		Fine, printable granulation produced by electrolytic action on the bare surface of the metal on plates etched by electrolysis. An effect similar to traditional aquatint.
Electrotyping *Galavanoplasty*		It consists of producing metallic copies of models of different materials

Embossing *Deep bite / Dry relief*		See: Dry relief
Etching		This is a generic name for all processes using intaglio etching techniques in which metal is corroded by acid, salt or electrolysis. The process corrodes an image drawn on a metal plate which is then printed .
Ethanol *Ethyl alcohol*	CH_3CH_2OH	Colourless and flammable liquid with a boiling point of 78 °C. In the etching workshop it is used to lift glass paint and also dry engraving ink used as hard grounds, also used in the composition of some resists.
Ethyl alcohol *Ethanol*	CH_3CH_2OH	See: Ethanol
Ferric chloride *Iron chloride*	$FeCl_3$	A salt of somewhat hydrosoluble iron and hydrochloric acid, with a tendency to become alkaline. It is used dissolved in water to bite copper plates. The ferric chloride reacts with the copper creating ferrous chloride.
Ferrous sulphate *Green vitriol*	$FeSO_4$	Called green vitriol, is a chemical compound derived from iron which forms as green crystals. It is used to electro-etch iron plates, as a mordant in dye, as medicine in tonics, and also in the manufacture of ink and pigments.
Flat biting *Crevé*		Wide flat depressions without tooth, even if deeply bitten, will be wiped out as the printer clears the surface ink from the plate.
Foul bite		Unintentional marks or fine dots and irregularities bitten into a plate because the grounds were not applied well or the grounds do not resist the mordent action.
Furrow *Groove*		Indentation on a plate due to etching, by any direct or indirect intaglio process, the marks made by the artist-etcher –the original drawing on the plate.
Fusion *Melting*		Physical process which consists of the change in state of the material, from solid state to liquid state by heating: applies to waxes, rosin, grounds.
Galvanism		Electricity produced by a chemical reaction, created by the contact of two different metals, generally copper and zinc, with a liquid interposed.

NAME *SYNONYMOUS*	FORMULA *SYMBOL*	DESCRIPTION
Galvanography *Electrotype / Galvanograph*		Electrolytic procedure consisting of the reproduction of a copper or zinc plate via electrolytic recovery from a mould of the same metal. Connected to the negative pole, it is coated by the metal from the positive pole. The mould is removed and the copper coating creates a reproduction of the mould, which can be printed in the same manner as engraved plates.
Galvanoplasty *Electroplating*		Technique which consists of the reproduction of metallic objects by electrolytic galvanisation from a mould of various materials, from which the metallic coating can later be removed. It is principally used in the manufacture of, recording matrices, medals, etc.
Graining		A method of producing the texture or “grain” on a limestone slab or metal plate for lithography.
Gramme *Gram / gm*	*g*	Unit of mass of the metric system.
Graphite *Plumbago / Blacklead*		One of the elemental forms in which carbon can be found; another is diamond. It is black in colour with a metallic shine, it is refractory and is easily exfoliated. It is an electrical conductor and is used in the manufacture of electrodes. It is used in galvanography to conduct electricity around the surface of the mould.
Graphite intaglio ink		Ink made with linseed oil and graphite powder. Used in electrolysis to achieve the unique effect of microdot.
Green vitriol *Ferrous sulphate*	$FeSO_4$	See: Ferrous sulphate.
Groove *Furrow*		See: Furrow
Ground *Resist / Varnish*		Any material that is spread on the plate which, once dry, blocks the action of mordants. It can be any type of material: varnishes, paint, oil pencils, self-adhesive plastics, etc. They can be difficult to remove after use.
Gum Arabic *Acacia gum / Gum syrup*		See: Acacia gum

Gum syrup *Acacia gum / Gum arabic*		See: Acacia gum
Halftone		It is the reprographic technique that simulates continuous tone imagery through the use of dots, varying either in size, shape or spacing.
Hard ground		Substance which resist or blocks the action of the mordant, dries quickly, and is applied to the plate with a paintbrush or a roller, and once dry, the plate can be worked on with metal etching points. Melts at a higher temperature than soft ground.
Hydrochloric acid *Muriatic acid / Spirits of salt*	HCl	Strong acid formed by hydrogen chloride gas dissolved in water. It is a colourless or slightly yellow solution, is very corrosive and emits toxic fumes. It attacks the majority of metals. It is used in Duch mordant.
Hydrogen	H	Flammable, colourless and odourless gas. It is the lightest chemical element and the most abundant in the universe. In addition, it appears in a multitude of chemical substances like, for example, water and organic compounds. It reacts with the majority of elements. It is generated at the cathode of the electrolytic process when the voltage rises above the safety level, in the passive electro-etching process and in the sacrificial metal electrolytic process.
Intaglio		A process of printing in which the image is drawn into the surface of a plate. The drawing is made of cavities, textured effect, incised, scratched or corroded. An intaglio plate normally involves using etching, drypoint, or engraving processes
Intaglio ink		Ink made with linseed oil and pigments for printing etchings.
Ion		Electrically charged atom or group of atoms. Normally water soluble ions are attracted to the electrodes of the opposite charge. Metallic ions are converted into metal on contact with the cathode.
Isopropanol *Isopropyl alcohol*	C_3H8O “or” $(CH_3)_2CHOH$ *IPA*	Colourless liquid, flammable with strong odor, mixes well with water. Used to lift acrylic grounds stuck fast to plates.
Isopropyl alcohol *Isopropanol*	C_3H8O “or” $(CH_3)_2CHOH$ *IPA*	See: Isopropanol

NAME *SYNONYMOUS*	FORMULA *SYMBOL*	DESCRIPTION
Lift-ground process *Sugar-lift aquatint*		Method of drawing or painting marks in an etching. Based on the incompatibility of the resist and a different substance used to draw on a plate and that will lift the layer of resist, leaving the bare metal to be etched. Commonly known as sugar-lift aquatint because of the process of lifting the protective ground layer with a mixture of Indian ink and sugar, and because of aquatint produced by asphaltum powder or rosin on a plate bitten with an acidic solution. The new etching grounds require different lift solutions.
Lithography		A printing technique using a prepared “stone” or metal plate which utilises the fact that an oil based ink will only adhere to a greasy image and not to a surface dampened with water.
Melting *Fusion*		See: Fusion
Methanol *Methyl alcohol*	CH_3OH	A light, flammable, colourless and toxic liquid that is used as antifreeze, industrial solvent and fuel. It is used as a solvent for inks, dyes, resins and adhesives.
Methyl alcohol *Methanol*	CH_3OH	See: Methanol
Mezzotint		It is an intaglio process in which the plate is systematically stippled into a mass of regular indentations with a tool called a rocker. Such a plate would print black as with aquatint. The technique works from “black to white”: the design/image is formed by scraping and burnishing the stippled surface to the desired degree from black, gray to white tonals. New process to roughen the plates by electro-etching, aquatinting or galvanising the plates –a pseudo mezzotint.
Mordant		Solution of acid, salt or electrolyte with corrosive properties used to etch metal plates.
Muriatic acid *Hydrochloric acid / Spirits of salt*	HCl	See: Hydrochloric acid
Negative pole *Cathode*	*(-)*	See: Cathode

Nitric Acid	HNO_3	A corrosive liquid which gives off toxic fumes. Used in etching: dissolved in water to bite zinc, copper and iron plates. Mixed with hydrochloric acid (aqua regia) it will dissolve gold.
Nitrogen dioxide	NO_2	A toxic, dark brownish-grey oxidised gas. It is usually produced by the reaction of nitric acid with the metal plates used for etching.
Open bite		Used in this handbook to mean a wide area of the plate, where bare metal will be bitten.
Orange Oil Leinos Thinner 200 (new name: Leinos-Verdünnung 200)		Non-toxic cleaner composed of isoparaffin. It contains less than 1% orange peel oil to give it a noticeable smell for safety reasons, as due to its transparency it could be confused with a liquid (water) and be ingested accidentally. It is used for cleaning inks from plates and tools. In electro-etching it can be used mixed with graphite ink to create tonal effects on copper, zinc and iron plates.
Oxygen	O	A colourless, odourless and tasteless gas. It represents approximately 20% of the composition of the atmosphere of earth. It is generated at the anode of the electrolytic process when the voltage rises above the safety level or in the sacrificial metal electrolytic process.
Passive electrolytic etching		Etching process based on the principle that two different metals, submerged in the correct solution, facing each other and in parallel and connected electrically outside the electrolyte, generate a flow of electric current sufficient to displace ions. A zinc plate will be etched if facing and connected to a plate of copper, both of which are submerged in a copper sulphate solution.
pH	*ph*	Measure of acidity or alkalinity of a solution. A pH of 7 is a neutral solution, solutions with higher values will be basic or alkaline, and lower will be acidic.
Photopolymer		Material made with polymers which change their properties upon being exposed to ultraviolet (UV) light. In the form of emulsion and photopolymer film; can be used as resist for etching with electrolysis.
Plumbago *Graphite*		See: Graphite
Positive pole *Anode*	(+)	See: Anode

NAME *SYNONYMOUS*	FORMULA *SYMBOL*	DESCRIPTION
Power supply *DC power s.*		See: Direct Current power supply
Propanone *Acetone*		See: Acetone
Resist *Ground / Varnish*		See: Ground
Rinsing tank		Tank containing water for washing off the etched plate; iron filings are added for washing copper plates etched by electrolysis –this avoids the direct discharge of copper sulphate residues into the water system, which would be affected by copper sulphate.
Roll-over *Roll-up / Viscosity printing*		An inking technique for applying three different colours at the same time, on a relief plate.
Roll-up *Roll-over / Viscosity printing*		See: Roll-over
Rosin		A resin obtained from pines and some other plants, mostly conifers, produced by heating fresh liquid resin to vaporize the volatile liquid terpene components. It has a melting point of approximately 93ºC. Will give off toxic fumes if overheated. For the aquatint technique it is used in a fine dust and melted on the plate. It is present in traditional grounds.
Sacrificial anode etching *Sacrificial metal etching*		Electro etching process based on the difference of the electrochemical potential between two metals. The less noble metal, the one with a more negative electrochemical potential, corrodes (is sacrificed) leaving the other metal unaffected.
Sacrificial metal etching *Sacrificial anode etching*		See: Sacrificial anode etching
Saline sulphate mordant		Generic name for saline solutions with mordant properties. Usually composed of copper sulphate and common salt. Used for zinc, iron and aluminium plates.

Saturation		As salts are added to water and dissolved, a point is reached where further amounts cannot be dissolved –the solution is saturated.
Semi-dry electrolytic etching		Etching process in which the plate is not submerged in a tank of electrolyte. The electrolytic process is produced through a piece of felt which, soaked in electrolyte, is placed between the plate that is to be etched and the cathode plate; the plates are then connected to a power supply.
Short circuit		A fault condition where a direct connection or "short" is made between the anode and cathode, possibly causing a large flow of current and damage to the power supply. Some power supplies may have built in protection against short circuits.
Sodium bisulphate	$NaHSO_4H_2O$	Salt used in some recipes of saline mordant for aluminium plates, together with copper sulphate and common salt.
Sodium carbonate *Washing soda*	Na_2CO_3	White, translucent salt, among other things used in the manufacture of soap, glass and inks. It is used to develop photopolymer film, diluted in water to lift acrylic grounds, and neutralise the saline mordants with a copper sulphate base, once they have been exhausted.
Sodium chloride *Common salt / Table salt*	NaCl	See: Common salt
Sodium Polyacrylate	$[CH_2CH(COONa)]n$	Also known as "waterlock", is a super absorbent polymer. It has the ability to absorb as much as 200 to 300 times its mass in water. Acrylate polymers generally are considered to possess an anionic charge. It is used in consumer products such as nappies, detergents, agriculture.
Soft ground		Substance which resists or blocks the action of the mordant, dries slowly, and is applied to the plate with a spatula or roller and allows work on the plate by pressing in textured surfaces or using the crayon technique of drawing with a pencil through a piece of paper onto the plate.
Solution *Dissolution*		See: Dissolution
Spirits of salt *Hydrochloric acid / Muriatic acid*	HCl	See: Hydrochloric acid

NAME *SYNONYMOUS*	FORMULA *SYMBOL*	DESCRIPTION
Spit bite		A process to achieve variations of tone applying the acid solution directly on the plate with a brush, rather than submerging the plate in the acid bath.
Steel-facing		Electrolytic deposition of a thin layer of iron, nickel or chromium on a plate that has already been etched in order to increase the plates durability and, thereby, increasing the number of copies that can be printed. It is called nickel-facing if the layer is nickel or chromium-facing if the layer is chromium.
Stop-out resist *Stopping-out varnish*		Quick drying varnish that is applied on a plate which has already been etched in order to protect certain areas from further successive phases of biting.
Stopping-out varnish *Stop-out resist*		See: Stop-out resist
Sugar-lift aquatint *Lift-ground process*		See: Lift-ground process
Sulphuric acid	H_2SO_4	A highly corrosive liquid. It is the most widely produced chemical compound in the world. A great deal of it is used in the production of fertilisers. It used to be called oil of vitriol or vitriolic acid because it is made from this mineral. There were etchers who added a small amount of sulphuric acid (0.03% / litre of solution) to their copper sulphate solution to prevent unwanted oxidations.
Table salt *Common salt / Sodium chloride*		See: Common salt
To galvanise		Action which encompasses the various electrolytic techniques through which a piece of metal is coated with a layer of the same or a different metal.
Varnish *Ground / Resist*		See: Ground

VCA *Vegetable Cleaning Agent*		A range of non-toxic products approved in Europe for dissolving inks and oil resists. Composed mainly of vegetable oils, some can contain alcohol, others can be diluted in water without losing their solvent power.
Vegetable Cleaning Agent *VCA*		See: VCA
Vinegar *Acetic acid*	CH_3CO_2H	See: Acetic acid
Viscosity printing *Roll-over / Roll-up*		See: Roll-over
Volt	*V*	The unit used for the electrical potential, the electromotive force and the voltage.
Voltage		The difference of the potential between two points. In order to produce a flowing current of electricity between two points, a difference of potential must exist between them.
Washing soda *Sodium carbonate*	Na_2CO_3	See: Sodium carbonate
Whiting *Calcium carbonate*	$CaCO_3$	See: Calcium carbonate.
Wiping		The process of cleaning the ink from the surface of an intaglio plate, leaving ink only in the lines and furrows to be printed. The plate is usually wiped with a ball of tarlatan followed by tissue paper or chalk applied with the palm of the hand.
Zinc sulphate	$ZnSO_4$	A chemical compound derived from zinc which forms whitish water soluble crystals. It is used to electro-etch zinc plates, although the principal application of the zinc sulphate is to galvanise steel for protection against corrosion. It is also used in batteries.

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In *Electro-etching handbook –a safe, non-toxic approach*, Alfonso Crujera takes us step by step through the practical application and processes involved in this new technique which is much healthier for printmakers and more environmentally friendly. An alternative to traditional intaglio methods with acids, rosin, and asphalt, electro-etching is simple and inexpensive. The wide range of techniques which it offers enables printmakers to develop their graphic skills.

With a preface by Friedhard Kiekeben, artist, graphic researcher and editor of *Nontoxic Printmaking & Printed Art*, this English edition is a revised and expanded version of the Spanish handbook with new processes that enrich the practice of electrolytic etching.

Throughout the 206 pages of the handbook, processes, formulas and proofs are explained in step by step detail, with the help of 240 photographs, 9 data charts and a glossary of 147 entries. The manual also contains reproductions of prints by artists who have successfully exploited these new techniques.

Photograph: J M Febles

Painter, sculptor, printmaker and Professor of intaglio at Luján Pérez Art School between 1999 and 2010, Alfonso Crujera has lived and worked on the island of Gran Canaria since 1968. He has had numerous solo and group exhibitions, and participated in other disciplines such as the field of theater, performance and video.

In 2001 he began electrolytic-etching at the Atelje Larsen, Helsingborg, Sweden. In 2002 he installed in his studio on the coast of San Felipe, the first electrolytic etching workshop in Spain. Since then he has given numerous courses and lectures on Electro-etching at conferences, universities and workshops in Spain and Mexico.

In 2008 he published the Spanish edition of the handbook on Electro-etching. Among other publications, he has written articles for the magazine *Grabado y Edición* and for the website *Nontoxic Printmaking & Printed Art*. A member of Res Artis and Trans Artists, his studio offers a residency program for artists interested in electrolytic etching technique. To date, artists from Argentina, Brazil, Canada, Costa Rica, Cuba, Estonia, Italy, Mexico, Paraguay, Poland, Spain, South Korea, UK and USA have been trained in this technique while residents in his studio.